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Numerical Simulation of Foundation Pit Dewatering Based on FEFLOW-taking Pumping Station a as an Example

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Abstract: Pump station engineering, as one of the main methods of irrigation and drainage in water conservancy projects in China, can regulate water resources and meet the needs of economic and social development. However, during the construction process, it is easily affected by external factors such as weather, which can cause safety hazards such as water seepage and sand overturning. Therefore, it is necessary to carry out foundation pit dewatering and drainage, Taking pump station A as an example, using FEFLOW software to simulate the precipitation of foundation pits during construction and maintenance periods can provide reference for similar projects.

There is a large population concentration in cities, and if the drainage system is not perfect, it will have a constraining effect on urban development. Therefore, to ensure the safety of urban flood control and drainage, it has become a key focus of river flood control [1-4]. Urban flood control and drainage engineering facilities are an important component of urban infrastructure. As one of the main irrigation and drainage projects, the pumping station is prone to adverse situations such as pipe surge and soil flow during the construction process under the influence of external factors. Based on this, numerical simulation can be used to simulate the drainage size of the foundation pit under different conditions, and adverse situations can be pre discharged in advance [5-8].

1. Project Overview

A pump station is located on a large embankment in Anhui Province, and is one of the key construction projects for drainage pump stations in waterlogging prone areas. The station is designed with 5 installed units, a designed drainage flow of 38.60m3/s, an installed capacity of 3 units of 800kW, 2 units of 500kW, and a total installed capacity of 3400kW. Its main function is mechanical discharge and self discharge, with a designed flow rate of 33.18m3/s for self discharge and 38.6m3/s for mechanical discharge. Through scheme comparison, a combination of three 1600ZLB-7 water pumps and two 1400ZLB6.2-7 water pumps was selected for design, with a total installed power of 3400kW. The drainage inlet gate, forebay, pump house, pressure water tank, drainage outlet culvert, etc. are arranged in a forward direction, located on the same axis in sequence, and the axis is orthogonal to the embankment.

The geomorphic unit of the site is the river Alluvial plain, and the micro geomorphic unit is the Floodplain. The river where the pump station is located flows from north to south, and the width of embankments on both sides of the river channel is about 75m. The river elevation is 8.37m, the river bottom elevation is 6.52m, and the maximum elevation of embankments on both sides is 13.02m. The ground elevation of the plain area outside the embankment is 8.62m-12.64 (residential area). There is a large pond on the northeast side. The bottom elevation of the pond is about 7.92m, the water depth is about 1.0m, and the distance from the side wall of the forebay is 47m. The upper part of the groundwater type in this site is Quaternary loose rock pore phreatic water, and the lower part is confined water. Diving water mainly occurs in layer ③ of silt and layer ④ of silt, with moderate permeability; The lower confined water mainly exists in layer ⑥ of fine sand and layer ⑦ of pebble soil, which is highly permeable. The river water recharges the groundwater in rainy season and Groundwater recharge recharges the river water in dry season. The groundwater level is obviously affected by seasonal river level.

During the excavation of the bottom soil of the self pump room section and the control section of the water collection tank, three concentrated water outlet points were found at an elevation of approximately 2.00m. One of them (No. 3 water outlet point) was located outside the boundary line of the building structure, and the other two (No. 1 and No. 2 water outlet points) were located within the control section of the water collection tank. Small pipe 3 is about 3 meters away from the sideline, 130 meters away from the downstream cofferdam, and 55 meters away from the left bank pond, with a water level of 9.5 meters. The water outlet contains black sand and gradually collapses. Relevant emergency measures have been taken to address the situation of water accumulation, such as inverted filter enclosure wells, water pump drainage, etc. However, with the arrival of the rainy season, there are still water inrush situations in the foundation pit. In order to achieve a significant drainage effect in the foundation pit, numerical simulation calculations have been conducted.

1.1 Blended Teaching Model

Blended classroom is a model that integrates online platform courses with offline traditional classrooms. Compared with the traditional teaching method, which is mainly based on theoretical teaching and centered on textbooks, although it adheres to the "student-centered" educational purpose, it does not weaken the leading role of teachers. Combining the online platform class with the offline face-to-face class can broaden the learners' thinking and vision, so that students can absorb more different viewpoints [6]. In addition, the blended teaching method does not simply add online and offline teaching, but combines the two teaching methods to learn from each other's strengths and weaknesses. In online teaching, learners can achieve the autonomy of learning "time and space" , and can complete their studies in full accordance with their own needs, thereby improving the ability of independent learning. In offline classroom teaching, teachers can connect problems through the whole classroom teaching process, and in the process of teacher interaction and inquiry, make teachers get closer to students, go deep into students, interact with students more effectively, and mobilize their subject ability. In this process, they have mastered the skills of using existing knowledge to analyze problems. Blended teaching is a kind of concept of "teacher-led, student-centered", which fully integrates online teaching and traditional offline teaching, and gives full play to both. advantage of teaching methods.

2. Establishment of Numerical Model and Well Layout Plan

2.1 Establishment of Numerical Models

In order to reasonably determine the dewatering plan of the foundation pit and equip it with appropriate pumping equipment, it is necessary to analyze and calculate the total water inflow of the foundation pit dewatering, the water inflow of a single well, and the depth of groundwater in the foundation pit. The precipitation simulation calculation adopts the widely used groundwater seepage simulation software FEFLOW both domestically and internationally. FEFLOW software is a finite element method based simulation software system for groundwater flow and solute migration developed by DHI-WASY company. It carries the necessary tools for simulating each stage of groundwater flow, such as boundary generalization, modeling, post-processing, parameter adjustment, visualization, etc. This software is based on interactive graphical input and output and geographic information system (ARCGIS) data interface, which can automatically generate various finite element grids and perform spatial parameter regionalization. It adopts various fast and accurate numerical calculation methods internally, such as time step automatic optimization method. For non confined aquifers, it adopts the method of changing the upper boundary to adapt to changing groundwater levels [9-10].

The surrounding terrain of the foundation pit is flat. According to empirical formulas, the radius of influence of precipitation when the water level drop of the foundation pit is 6.3m is calculated to be 772m, which means that the change in groundwater level caused by pumping outside the foundation pit is very small and can be ignored. In this calculation, the calculation area is selected based on this radius of influence and appropriately expanded outward. 1000m away from the south and north of the foundation pit is designated as a Class II zero flow boundary, and about 150m away from the east side of the foundation pit is Qiupu River, Set it as a fixed head boundary, and the west side of the foundation pit is set as a type of fixed head boundary; The upper boundary is the free water level boundary, and the lower boundary is the impermeable bottom plate.

The groundwater types in the engineering area are divided into phreatic water and confined water. The formation lithology of the phreatic aquifer is composed of silt and silt, with a total thickness of approximately 4.5m. The formation lithology of the confined aquifer is composed of fine sand and pebble soil, mainly composed of pebble layers. The pebble layer has a thickness of about 8m, and the bottom layer is a weakly permeable layer, which can be regarded as a waterproof bottom plate. The permeability coefficient of the pebble layer is K=150m/d, and the water supply degree is 0.3.

This calculation uses the three-dimensional finite element method to discretize the model area into an irregular triangular grid. Considering the calculation speed and accuracy, larger calculation cells are used far away from the foundation pit. When approaching the scope of the foundation pit, the cells are encrypted and dissected, resulting in a total of 281382 units in the model. Vertically, there are 6 simulation layers, and the thickness of the simulation layer is generalized based on the layer thickness in Table 3.2-1. The total calculation range of numerical simulation is 2000m in length from east to west, 2000m in width from north to south, with a total area of 4.0km2 and a vertical thickness of 22m. The mesh generation and boundary conditions of the simulated area are shown in Figure 1.

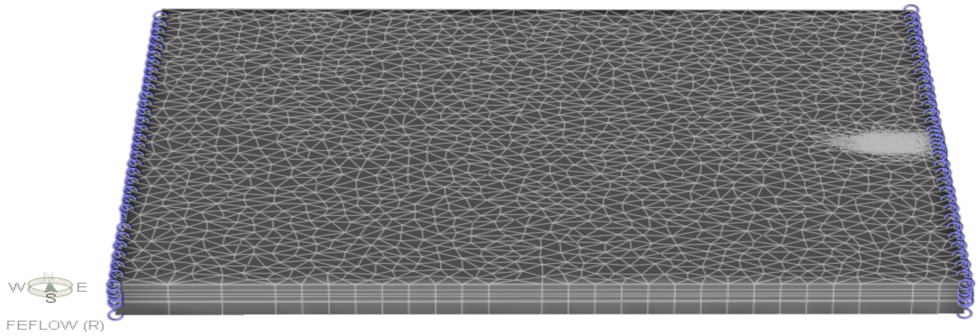
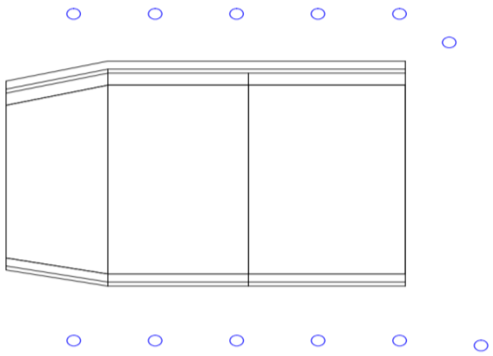


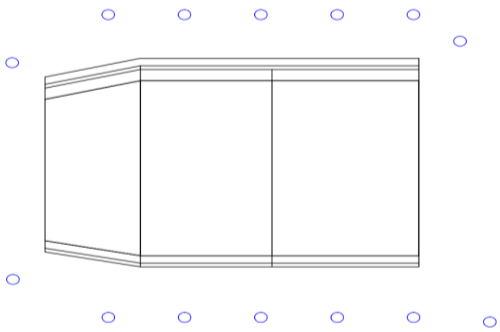
Figure 1. Model Boundary Conditions and Mesh Generation 3D View

2.2 Four Well Layout Schemes

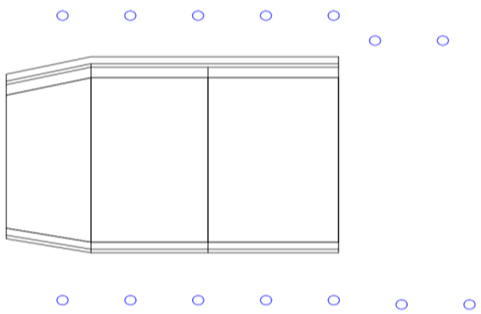
Different well layout schemes have different responses to aquifers (such as depth reduction and speed reduction). In order to better meet the actual needs of engineering construction, the water output and inflow of a single well that can lower the central water level of the foundation pit to 1m below the pit bottom (i.e. elevation 0.4m) are calculated. Based on the experience of previous foundation pit dewatering projects, the numerical model is designed with different numbers and positions of wells A total of 4 alternatives are compared for different total mining output combinations [11-16]. The model uses unsteady flow to solve the time required for the water level in the center of the foundation pit to drop to 0.4m under the conditions of different mining output during the construction period,See Figure 2 for details.



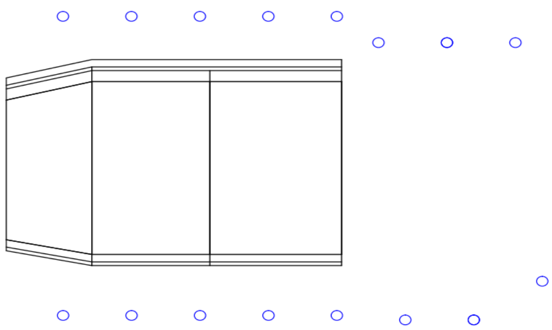
a.Option 1



b.Option 2



c.Option 3



d.Option 4

Figure 2. Schematic diagram of well layout plan

3. Project overview

3.1 Calculation of Precipitation Plan During Construction Period

During the construction period, the water level of the river is 9m, with a fixed head boundary of 9m on the west side and 6.5m on the east side. The initial groundwater level in the center of the foundation pit in the flow field is about 6.7m.

Table 1. List of Well Layout Plan Design during Construction Period

Calculation scheme	Single well water output(m^3/d)	Number of wells (Eye)	Total mining output($\times 10^4 m^3/d$)
1	2400	12	2.88
2	2400	14	3.36
3	2400	14	3.36
4	2400	16	3.84

Calculation Plan 1: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 0.4m when the drainage volume of the foundation pit is 28800 m3/d. Through calculation, it can be concluded that the groundwater level in the area near the center of the foundation pit can drop to 0.4m after 21.5 days of opening 12 drainage wells on both sides of the forebay during the construction period, meeting the needs of engineering construction.

Calculation Plan 2: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 0.4m when the drainage volume of the foundation pit is 33600 m3/d. Through calculation, it can be concluded that the groundwater level in the area near the center of the foundation pit can decrease from 6.7m to 0.4m after opening 14 drainage wells for 13.5 days during the construction period, meeting the needs of engineering construction.

Calculation Plan 3: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 0.4m when the drainage volume of the foundation pit is 33600 m3/d. Through calculation, it can be concluded that the groundwater level in the area near the center of the foundation pit can decrease from 6.7m to below 0.4m after opening 14 drainage wells for 12 days during the construction period, meeting the needs of engineering construction.

Calculation Plan 4: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 0.4m when the drainage volume of the foundation pit is 38400 m3/d. According to calculations, the groundwater level in the area near the center of the foundation pit can decrease from 6.7m to 0.4m after opening 16 dewatering wells for 8.5 days during the construction period, meeting the needs of engineering construction.

Comparing the duration curves of water level changes in the center of the foundation pit under four different conditions, the shape of the groundwater level change duration curve is basically the same under different single well pumping conditions. That is, the groundwater level in the foundation pit decreases rapidly during the initial stage of mining, but over time, the water level change duration curve tends to flatten and gradually reaches basic stability. Under different single well pumping conditions, the time required for the groundwater level in the center of the foundation pit to drop to 0.4m varies. The larger the total drainage, the lower the water level when the groundwater level reaches basic stability. The shorter the time required for the water level in the center of the foundation pit to drop to 0.4m, as shown in Table 2.

Table 2. Changes in Central Water Level and Required Time of Foundation Pit under Different Foundation Pit Drainage Conditions

pattern of wells	Single well pumping capacity(m3/d)	Number of wells(Eye)	Total mining output($\times 10^4 m^3/d$)	Time required for the water level in the center of the foundation pit to decrease from 6.7m to 0.4m (in days)
Option	2400	12	2.88	21.5
Option	2400	14	3.36	13.5
Option	2400	14	3.36	12
Option	2400	16	3.84	8.5

Due to the close relationship between the single well water output of a dewatering well and the geological structure and construction quality, it usually fluctuates within a certain range. Therefore, when arranging the construction schedule, the actual water output of the dewatering well should be considered to avoid the groundwater level not falling to the design elevation in a timely manner, which will affect the construction progress and slope stability.

3.2 Calculation of Precipitation Plan During Maintenance Period

During the maintenance period, the water level of the river is 9m, the water level in the forebay is 2.25m, the fixed head boundary on the west side is 9m, and the fixed head boundary on the east side is 6.5m. The initial groundwater level in the center of the foundation pit in the flow field is about 6.7m. The model uses unsteady flow to calculate the time required for the central water level of the forebay to drop to 2.0m under the conditions of different mining output during the maintenance period. The well layout plan is the same as that during the construction period, as shown in Figure 2. The calculation results are as follows:

Calculation Plan 1: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 2.0m when the drainage volume of the foundation pit is 28800 m3/d. Through calculation, it can be concluded that during the maintenance period, the groundwater level in the area near the center of the foundation pit can decrease from 6.7m to 2.0m after opening 12 dewatering wells on both sides of the forebay for 7 days, meeting the needs of engineering construction.

Calculation Plan 2: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 2.0m when the drainage volume of the foundation pit is 33600 m3/d. According to calculations, the groundwater level in the area near the center of the foundation pit during the maintenance period can decrease from 6.7m to 2.0m after opening 14 dewatering wells for 6 days, meeting the needs of engineering construction.

Calculation Plan 3: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 2.0m when the drainage volume of the foundation pit is 33600 m3/d. Through calculation, it can be concluded that during the maintenance period, the groundwater level in the area near the center of the foundation pit can decrease from 6.7m to 2.0m after opening 14 dewatering wells 5.5 days, meeting the needs of engineering construction.

Calculation Plan 4: Estimate the time required for the center water level of the foundation pit to decrease from 6.7m to 2.0m when the drainage volume of the foundation pit is 38400 m3/d. According to calculations, the groundwater level in the area near the center of the foundation pit during the maintenance period can decrease from 6.7m to 2.0m after opening 16 dewatering wells for 4.5 days, meeting the needs of engineering construction.

Comparing the duration curve of the central water level change in the foundation pit under four different conditions, the shape of the groundwater level change duration curve is basically the same under different single well pumping conditions. That is, the groundwater level in the foundation pit decreases rapidly during the initial stage of mining, and over time, the water level change duration curve tends to flatten and gradually reaches basic stability. The specific time is shown in Table 3.

Table 3. Changes in the central water level of the foundation pit under different drainage conditions and the required time

pattern of wells	Single well pumping capacity(m3/d)	Number of wells(Eye)	Total mining output($\times 10^4 m^3$/d)	Time required for the water level in the center of the foundation pit to decrease from 6.7m to 2.0m (in days)
Option 1	2400	12	2.88	7
Option 2	2400	14	3.36	6
Option 3	2400	14	3.36	5.5
Option 4	2400	16	3.84	4.5

Under different single well pumping conditions, the time required for the groundwater level in the center of the foundation pit to drop to 2.0m varies. The larger the total drainage amount, the lower the water level when the groundwater level reaches basic stability, and the shorter the time required for the water level in the center of the foundation pit to drop to 2.0m.

4. Conclusions

By using the groundwater seepage simulation software FEFLOW to calculate and analyze the foundation pit dewatering and drainage of pump station A during the construction and maintenance periods, it can be concluded that under different single well pumping conditions, time varies. The larger the total drainage amount, the lower the water level when the groundwater level reaches basic stability, and the shorter the time required. However, during the construction period, due to the close relationship between the single well dewatering water output and the geological structure and construction quality, Usually fluctuates within a certain range.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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