Research on precipitation Simulation of Water-rich Subway Station based on Visual Modflow

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Abstract. Based on the foundation pit dewatering and recharge engineering of a subway station in Jinan City, the groundwater control technology of foundation pit engineering based on fluid-solid coupling is studied in this paper. With the measures of setting deep and shallow recharge wells and dewatering construction of foundation pit at the same time of dewatering and recharging, the actual foundation pit dewatering engineering is simulated by visual 3D groundwater flow simulation software Visual Modflow. The additional stress principle of soil is used to analyze the land subsidence. The software makes full use of the characteristics of flexible determination of well location, number of wells, well structure, water inflow, well diameter and so on in the foundation pit, and realizes the visualization, anticipation and verification of the design dewatering process at the same time. The reliability of the method is proved and a new way of dewatering design for foundation pit in the future is provided.

1. Introduction
In the construction of high-rise buildings and underground works, deep foundation pit engineering is usually affected by groundwater, and precipitation measures are often needed to ensure the convenience and safety of foundation pit construction. Foundation pit dewatering may also have a certain degree of impact on the surrounding environment while ensuring construction convenience and safety[3]. As the groundwater level decreases, the soil undergoes consolidation and deformation, resulting in different degrees of settlement deformation and differential settlement between the surrounding surface, buildings and pipelines, resulting in serious economic losses and many adverse social impacts[4].

At present, in the study of land subsidence caused by foundation pit dewatering, domestic and foreign scholars usually use numerical calculation methods to analyze the coupling effect in the process of foundation pit dewatering, and obtain some research on the study of seepage and deformation law of foundation pit precipitation[1]. However, the comprehensive analysis of land subsidence caused by different construction measures is still unclear. Therefore, this paper uses Visual Modflow software to analyze the deepening of groundwater inside and outside the curtain curtain during the construction of a subway station in Jinan City, the characteristics of water layer consolidation and the change of groundwater level with time, and guide the foundation pit precipitation[2]. Design optimization has a positive guiding significance.
2. Project Overview
The subway station is constructed by open cut method. The support system is the underground continuous wall + inner support support system, and the underground continuous wall also serves as the water stop curtain. From top to bottom, the stratum is 1-1 mixed soil, 1-2 plain fill, 7 clay, 7-1 silty clay, 10-1 silty clay, 19-1 fully weathered diorite, 19-2 Strongly weathered diorite, 19-3 middle weathered diorite.

3. Groundwater overview
The groundwater stable water level is buried between 0.7 and 3.2 m, and the elevation is between 20.60 and 22.92 m. It is a type of submerged in the Quaternary loose layer pores and the underlying bedrock fissures.

1) Quaternary loose layer pore diving, The main aquifer is 1-1 layer of mixed soil, 1-2 layer of filling soil bottom, 7-1 layer of silty clay, 10-1 layer of silty clay. Among them, 1-1 layer, 1-2 layer artificial filling bottom, 10-1 layer silty clay is the main aquifer, and 7-1 layer silty clay is relatively small in water solubility and permeability.

2) Bedrock fissure diving, Occurred in the Quaternary underlying bedrock fissure and tectonic fissure, it belongs to the bedrock fissure type, and the aquifer is mainly 19-1 layer fully weathered diorite and 19-2 layer strongly weathered diorite.

4. Precipitation well plan layout and model establishment

4.1. Precipitation well plan layout
There are 21 wells in the pit, and the double-row plum blossoms are arranged. The lateral spacing of the precipitation wells is 16.1m, the longitudinal spacing is 18m, and the well depth is 26m. The distance between the shallow recharge well and the deep recharge well around the foundation pit is 6.78m~9.53m. The shallow recharge well and the deep recharge well are arranged at intervals. A total of 22 deep recharge wells are arranged on site, and the shallow recharge well 23 The shallow recharge well has a hole depth of 15.0m and enters the 19-1 fully weathered diorite layer. The deep recharge well has a hole depth of 26.0m and enters the 19-2 diorite basement. The initial water level around the foundation pit is 1m underground.

Note 1: CS1-1# pumping well; Q1-1# shallow recharge well; S1-1# deep recharge well.

Figure 2-1. Foundation pit profile

Figure 4-1. Precipitation well plan layout

Figure 4-2. Model plan
4.2. Model establishment

The length of the foundation pit is about 207m, the width is about 23.7m, and the foundation pit is 16.5m deep. According to the geographical situation of the study area, it extends 300m to both sides of the east and west, and extends 100m from north to south. It forms a rectangle with an area of 807m*223.7m and a simulated depth of 34.5m. It fully considers the influence of topographic changes on precipitation and the actual elevation of the input. Mesh the study area, 150 columns (north-south direction), 50 lines (east-west), in order to make the results more accurate, more reflect the precipitation funnel curve, the local encryption segmentation of the grid, mainly concentrated around the pit as shown in Figure 4-4. Vertically downwards, the entire Quaternary Holocene flooding (Q\text{4al+pl}) silty clay and the underlying Yanshanian (δ_5^3) gabbro and diorite are divided into eight layers, from top to bottom. For: 1-1 mixed fill, 1-2 plain fill, 7 clay, 7-1 silty clay, 10-1 silty clay, 19-1 fully weathered diorite, 19-2 strong weathered diorite 19-3 middle weathered diorite.

Table 4-1. Hydrogeological Parameters Table

| stratum          | kx (m/s) | ky (m/s) | kz (m/s) | s_s (1/m) |
|------------------|----------|----------|----------|-----------|
| first floor      | 9.00E-03 | 9.00E-03 | 9.00E-04 | 1.00E-05  |
| second floor     | 1.20E-05 | 1.20E-05 | 1.20E-06 |           |
| Third layer      | 2.90E-05 | 2.90E-05 | 2.90E-06 |           |
| Fourth floor     | 1.70E-04 | 1.70E-04 | 1.70E-05 |           |
| Fifth floor      | 1.20E-04 | 1.20E-04 | 1.20E-05 |           |
| Sixth floor      | 1.20E-06 | 1.20E-06 | 1.20E-07 |           |
| Seventh floor    | 1.20E-06 | 1.20E-06 | 1.20E-07 |           |
| Eighth floor     | 1.20E-06 | 1.20E-06 | 1.20E-07 |           |

Table 4-2. Single well pumping and recharge

| pump discharge (m³/d) | Shallow well recharge (m³/d) | Deep well recharge (m³/d) |
|-----------------------|------------------------------|---------------------------|
| 17                    | 7                            | 7                         |

According to the geological survey report and the pump station design plan, the entire study area boundary is divided into upper boundary: The upper boundary of the study area is mainly subjected to atmospheric precipitation infiltration replenishment, which can be calculated according to the calculation of human permeability coefficient and rainfall in the study area, and is set as the water exchange boundary.

5. Analog result

5.1. Draw down
The simulation results show that the water level in the water stop curtain of the subway station reaches 17.635m below the ground, and the water level outside the water stop curtain reaches 3.494m below the ground.

5.2. *Analysis of surface settlement*

The calculation is carried out using the principle of additional pressure of the soil. First, the stress state between the skeletons of the soil is set in a dry uniform soil layer, and the stress due to the self-weight of the soil is linearly distributed in the vertical direction (see line AB in Fig. 5-4)\(^5\).

![Figure 5-4. Stress distribution diagram under precipitation](image)

The lateral distance in Figure 5-10 represents the stress on the corresponding horizontal plane, which is equal to:

\[
\sigma = \gamma (1 - n) h
\]

**Type center:**
\[\gamma\] — Specific gravity of soil
\[n\] — Porosity of soil
\[h\] — The depth from the surface to a plane.

If the soil is below the groundwater level, the load per unit area at a certain level is composed of the weight of the soil above the horizontal plane and the weight of the water in the pores of the soil. The load is \(P\).

\[
P = \gamma (1 - n) h + \delta n h_i
\]

**Type center:**
\[h\] — The distance from a certain plane to the groundwater level.
\[\delta\] — Specific gravity of water.

The pressure distribution between the soil skeletons below the water table is indicated by AC. If the groundwater level is lowered by \(S\) (m), that is, the groundwater level moves to LE, and there is no water present in the pores of the soil, the hydrostatic pressure is reduced, and the amount of water flowing out of the soil column at \(h\) height is equal to \(\delta s\). Therefore, the pressure between the skeletons of the soil below the groundwater level increases \(\delta s(1 - n)\) in any horizontal section. At the height of \(h_1\), the pressure in the soil skeleton is distributed linearly AD. If the soil pores are completely filled with water due to the capillary force, the pressure increase between the skeletons of the soil below the LE line is \(\delta s\), and the surface is distributed at a line AE at the line pressure.

Therefore, the settlement of soil \(\omega\) can be calculated by the following formula:

\[
\omega = \frac{\Delta P H a}{1 + e}
\]

**Type center:**
\[\Delta P\] — Additional pressure of upper soil skeleton
\[H\] — Compression layer thickness of soil
\[a\] — Coefficient of compression of soil
\[e\] — Void ratio

From the site survey report, \(\gamma\) soil = 1.92g/cm\(^3\), \(a=0.43\), \(e=0.77\), calculated \(n=0.43\), groundwater stable water level buried depth 0.7–3.2m, the foundation pit water stop The water level outside the curtain is at least 3.5m underground. The water level is reduced by 2.8m according to the minimum 0.7m of natural stable water level.

(1)not taking into account the effect of capillary force: Horizontal unit area \(\Delta P\) : \(\Delta P=\delta s(1-n)=9.8*10^{-3}*2.8*(1-0.43)=15.64*10^{-3}\)MPa.
Soil settlement $\omega$: $\omega=15.64 \times 10^{-3} \times 2.8 \times 0.43/(1+0.77)=0.0106m=10.6mm$.

(2) Consider the effect of capillary force: Horizontal unit area $\Delta P$: $\Delta P=\delta s=9.8 \times 10^{-3} \times 2.8=27.37 \times 10^{-3}MPa$.

Soil settlement $\omega$: $\omega=27.37 \times 10^{-3} \times 2.8 \times 0.43/(1+0.77)=0.0186m=18.6mm$. The building settlement control value is 20mm, which meets the requirements.

6. Conclusion

(1) Visual Modflow software has a powerful three-dimensional groundwater simulation function. The finite difference method is used to reasonably reflect the changes of the terrain and the subdivision of the local grid, which fully depicts the surrounding conditions of the precipitation well. With the support of detailed hydrogeological survey reports, the software can simulate the deepening and flow of groundwater level well. In the actual project, the groundwater level change caused by foundation pit dewatering is reasonably simulated and predicted, which has certain reference value. To provide the corresponding guarantee basis for the foundation pit precipitation workers.

(2) Using the numerical simulation method to calculate the foundation pit dewatering, the number, position, structure and water consumption of the precipitation well can be flexibly adjusted according to the design requirements and the simulation test results, which can effectively shorten the precipitation design calculation process and pass various trial calculations optimize the precipitation program.

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