Numerical modeling of foundation pit dewatering based on Visual Modflow

Weiping Lu1,*, Zhisheng Chen1, Rongpeng Wu1, Zhichao Zhang2,3
1Longyan Violet Paradise Sports Park Investment Development Co., Ltd, Fujian Longyan 364000
2Key Lab of Geohazard Prevention of Hilly Mountains, Ministry of Natural Resources of China, Fuzhou 350002
3Engineering Technology Innovation Center for Monitoring and Restoration of Southeast Ecological Fragile Area, Ministry of Natural Resources of China, Fujian 350001

*Corresponding author: luwp@zjstygy.com

Abstract. After the investigation of a foundation pit project and the preliminary determination of the precipitation design scheme, the distribution of water level drawdown and land subsidence in the whole site was simulated by Visual Modflow software. The simulation results show that by setting the pump output of the 14 confined dewatering wells in the pit varying from 70 ~ 420 m³/day, the drawdown of the foundation pit can be uniformly reduced to about 4m. Due to the waterproof curtain, the waterline distribution inside the foundation pit is relatively uniform, which proves the rationality of the setting of the pumping well. At the same time, the waterline contour around the edge of the curtain is very intensive, indicating that there is huge difference in the drawdown between inside and outside of the waterproof curtain. The curtain plays an effective role in controlling the drawdown inside and outside the pit foundation, hence, the compression deformation and settlement of the soil are also small so as to avoid the damage of the surrounding buildings due to the uneven settlement of the ground surface. Therefore, the precipitation design has achieved a good effect.

Keywords: Foundation pit, Dewatering, Visual Modflow, Numerical modeling.

1. Introduction

With the continuous advancement of urban construction, numerous deep and large foundation pits have been born at the historic moment [1-4], causing a large number of engineering safety risks and construction difficulties. The difficulty of the foundation pit engineering lies in that due to its complex engineering geological background, many technologies lagging behind the practice are often applied in advance [5]. At the same time, the difference of groundwater conditions in each foundation pit also makes it difficult to apply the previous engineering case experience directly [3, 6-8]. Therefore, for the design of the foundation pit, it is particularly important to analyze specific problems and put forward
targeted design schemes and measures specifically for the engineering background so as to meet the economy, rationality and safety of the foundation pit design.

The foundation pit dewatering is also a crucial link in the foundation pit engineering, which directly determines whether the foundation pit engineering is safe and feasible. Therefore, after analyzing the general situation of a foundation pit project, this paper designs the precipitation scheme, and uses Visual Modflow software to conduct numerical modeling of the precipitation effect, which aims to preliminarily judge the effectiveness of the design scheme.

2. Project profile

2.1. Geotechnical condition

The excavation area of the foundation pit is about 12000m², and the elevation of the basement floor is -11.25m. According to the geological conditions of the site and other factors, the safety grade of this foundation pit project is determined as a level one. A typical engineering geological profile is shown in Figure 1. The rock and soil layer from top to bottom is roughly as follows: (1) miscellaneous fill: layer thickness 1.00 ~ 4.60m; (2) Silt: layer thickness 3.90 ~ 22.80m; (3) Silt and sand inclusion: the revealed layer thickness 5.80 ~ 18.90m; (4) Coarse sand (including mud): revealed thickness 1.90 ~ 22.40m; (5) Silty clay: revealed thickness 0.70 ~ 4.50; (6) Silty soil: revealed thickness 1.60 ~ 10.00m; (7) Pebble: revealed thickness of 0.30 ~ 8.10m; (8) Silty soil: revealed thickness of 1.70 ~ 5.90m; (9) Silty clay: revealed thickness 0.50 ~ 13.00; (10) Coarse sand (including mud): revealed thickness 1.40 ~ 21.60m; (11) Sand soil-like strongly weathered granite: revealed thickness of 3.60 ~ 31.70m.

![Figure 1 Typical engineering geology profile](image)

2.2. Groundwater condition

The buried depth of the initial groundwater level in the site is 0.90 ~ 5.10m (elevation is 0.77 ~ 5.11m), and the buried depth of the comprehensive stable groundwater level is 0.40 ~ 4.95m(elevation is 0.89 ~ 5.39m). The annual variation range of the groundwater level is 1.0 ~ 2.00m, the highest groundwater level in recent 3~5 years is 5.40m, and the highest groundwater level in history is 5.60m. The main conditions of groundwater are:

- Occurs in the upper stagnant water in the pores of the miscellaneous filling soil: its permeability is general and the range of variation is wide. The water level fluctuates greatly with the alternation of seasons, but the influence of the upper stagnant water on the foundation pit engineering is relatively weak.
Occurs in the layer (4) (containing mud) coarse sand, (5) pebble, (7) coarse sand (containing mud), the pore pressure water in the pebble: the permeability of each layer is medium ~ strong, rich in water is strong, the safety of the foundation pit engineering is greater.

Layer (4)~(5) and layer (7)~ (12) have direct hydraulic contact. Silt layer, silt sand, silty clay, silty soil is weak in water permeability and water abundance. They belong to weak permeable layer and are relative impermeable layer. The buried depth of confined groundwater level is about 15.30 ~ 17.99m (the elevation is -9.09 ~ -11.97m).

2.3. Excavation bursting analysis
In the formation (mud) coarse sand, the water level elevation of confined groundwater is -9.09 ~ -11.97m, the water level elevation of the confined groundwater is set as -9.09m, and the foundation pit floor elevation is -11.25m, then H=-11.25-(-14.09)=2.84m, h= -9.09-(-14.09)=5.0m, γw=10kN/m³, R=15.5kN/m³, \((γ_w/γ)•H=10×5.0/15.5=3.22m\), \(H=2.84m < 3.22m\). Hence, the excavation of the foundation pit may produce the phenomenon of surge.

3. Design of dewatering in foundation pit
Dewatering within the scope of foundation pit is mainly aimed at the pore confined water in (4) (mud) coarse sand, (5) pebble, (7) (mud) coarse sand and (8) pebble. Decompress the confined water as needed to ensure the stability of the foundation pit bottom surge. At the same time, a drainage well should be arranged every 200 m² around to drain the water in the pit.

3.1. Calculation of confined dewatering well
The water inflow of this foundation pit is calculated according to the pressure non-holonomic well. The average thickness of the aquifer is 25.47m, the weighted average of permeability coefficient is 23.7m/d, the depth reduction is 3.96m, the diameter of the dewatering well is 219, the inlet length of the filter is l=6m, the influence radius is R=486.83m, and the equivalent radius is r= 56.47m. Water inflow \(Q = \frac{2πk}{\ln(l+R/r)+(M−1)\ln(l+0.2M/r)} = \frac{5898.6m³/d}{ln(l+R/r)+(M−1)ln(l+0.2M/r)}\), single well water yield \(q_o = 120πr^l\sqrt{k} = 711m³/d\), therefore, the number of wells needed \(n=1.1×Q/q0≈10\). In order to ensure the effect of precipitation, 14 precipitation wells were actually arranged, and the depth of the wells was controlled by entering into the coarse sand layer and pebble layer (including mud) not less than 8m. The dewatering well layout is shown in Figure 2.

![Figure 2 Precipitation engineering layout](image-url)
3.2. Calculation of drainage well
According to experience, the effective radiation drainage area of this drainage well is about 250 m²/well, the calculated number of wells is $10013/250 \approx 40$, the actual layout is 48, and the well depth should exceed the basement floor and should not be less than 6m.

4. Modeling scheme of foundation pit dewatering

4.1. Calculation model
According to the actual situation, a numerical model was established (see Figure 3). The length, width and height of the model were 1000m×800m×100m respectively. During calculation, the periphery of the soil layer (4), (5), (7) and (8) (i.e., the boundary of the model) was set as constant water head, and the initial boundary condition of water head was given to the whole soil layer (4), (5), (7) and (8), so that the water head of the layer could change with pumping. Through trial calculation, the established numerical model and the final determined plane positions as well as pumping rates of each pumping well are shown in Figure 3. Figure 4 shows the geotechnical stratification and corresponding soil permeability coefficients.

![Figure 3 Analysis model and precipitation engineering layout](image)

![Figure 4 Geotechnical stratifications and soil permeability coefficients](image)

4.2. Result analysis

4.2.1. Drawdown analysis. The main object of dewatering is the soil layer (4). The contour map of soil layer (4) is shown in Figure 5. It can be found that the drawdown in the foundation pit generally reaches 4m, which roughly meets the design requirements. However, the maximum drawdown outside
the pit is only 0.5m, thus, the foundation pit dewatering can effectively control the ground subsidence and will not cause too much influence on the structures outside the foundation pit.

In addition, it can be found that the distribution of equal water head lines in the foundation pit is relatively uniform, which proves the rationality of the setting of pumping wells. Meanwhile, the contour lines at the edge of the curtain are very dense, which indicates that a large drawdown difference is generated inside and outside the curtain, and the curtain plays a role in controlling the drawdown inside and outside the pit. In the foundation pit inside the curtain, the water level should drop to a certain extent, and the drawdown is large so that the construction operation in the foundation pit can be carried out smoothly. On the outside of the curtain, the drawdown is small so that the soil deformation and settlement are small, thus, the surrounding buildings can avoid damage due to the uneven settlement of the ground.

![Figure 5](image1)

**Figure 5** Drawdown contour of soil layer (4) (unit: m)

The contour line of soil layer (7) is shown in Figure 6. As the soil layer (7) is located under the hanging waterproof curtain, the difference between the drawdown contour lines inside and outside the pit is significantly reduced. On the whole, the drawdown is relatively uniform, and there is no feature of dense distribution along the edge of the curtain.

![Figure 6](image2)

**Figure 6** Drawdown contour of soil layer (7) (unit: m)

4.2.2. *Land subsidence analysis*. See Figure 7 for land subsidence isolines. Because the waterproof curtain effectively controls the drawdown reduction outside the foundation pit, the ground settlement outside the foundation pit is relatively slight, the maximum value is only 0.4m, and it will not affect the daily operation outside the foundation pit.
5. Conclusion

After the investigation of a foundation pit project and the preliminary determination of the precipitation design scheme, the water level drawdown and land subsidence distribution of the whole site were simulated by Visual Modflow software. The specific conclusions are as follows:

1. By setting the pump output of the 14 confined dewatering wells in the pit varying from 70 ~ 420 m$^3$/day, the drawdown of the foundation pit can be reduced to about 4m evenly so as to meet the project requirements.

2. Due to the installation of waterproof curtain, the distribution of equal water headline in the foundation pit is relatively uniform, which proves the rationality of the pumping wells.

3. The isoline distribution at the edge of the curtain is very dense, which indicates that there is a huge drawdown difference between inside and outside the curtain. The curtain plays an effective role in controlling the drawdown inside and outside the pit, thus avoiding the damage of buildings around the foundation pit due to uneven ground settlement. Therefore, the precipitation design has achieved a good effect.

References

[1] Zhang X S, Feng C, Han Y S, et al. Accident Analysis and Emergency Response Effect Research of the Deep Foundation Pit in Taiyuan Metro [J]. Journal of Donghua University (English Edition), 2020, 37(03): 199-206.

[2] Zhang Q. Deformation analysis of deep foundation pit excavation in China under time–space effect [J]. Geotechnical Research, 2020, 7(3): 146-152.

[3] Niu J, Li Z, Feng C, et al. Combined support system and calculation model for deep foundation pits in fill soil areas [J]. Arabian Journal of Geosciences, 2020, 13: 1-15.

[4] Gu Q, Lee F H. Ground response to dynamic compaction of dry sand [J]. Geotechnique, 2002, 52(7): 481-493.

[5] Zhang Y, Chen W, Dou S, et al. Constructing Machine Tool Foundations Using an LMP Alloy [J]. Materials, 2020, 13(7): 1649-1657.

[6] Guo C, Wang R, Lin P, et al. Numerical analyses of a prefabricated retaining system for foundation pits in silt soils [J]. Geotechnical Research, 2020, 7(3): 173-190.

[7] Zhang, X S, Zhang, X C,Han, Y S, et al. A Case Study on Field Monitoring Analysis of Deep Foundation Pit in Soft Soils [J]. Advances in Civil Engineering, 2019, 11(4): 124-133.

[8] Mei Y, Li Y L, Wang X Y, et al. Statistical analysis of deformation laws of deep foundation pits in collapsible loess [J]. Arabian Journal for Science and Engineering, 2019, 44(10): 8347-8360.