Analysis of Factors Affecting the Water Inflow of Suspended Water Stop Curtain Foundation Pit Under Pressure Water Conditions

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Abstract. To analyze the factors affecting the water inflow of suspended water stop curtain foundation pits and study the water inflow patterns caused by the pressure reduction and precipitation process of pressurized water under different conditions, this paper adopts finite element numerical analysis method. Taking a suspended water stop curtain foundation pit project under construction in the water rich strata area of the Yangtze River floodplain as an example, by controlling a single variable, the factors that cause the water inflow of suspended water stop curtain foundation pits under the condition of containing pressurized water are analyzed one by one. The variation law of unit flow rate at half width of foundation pit with curtain distance under a single influencing factor is given. The results show that the inflow of confined water is directly proportional to the permeability coefficient, and both decrease with the increase of the depth of the water stop curtain; The water inflow increases with the increase of the water level drop in the foundation pit, decreases with the increase of the influence radius and increases with the increase of the excavation depth of the foundation pit; As the distance from the curtain increases, the amplitude of unit flow change gradually decreases; There is an optimal insertion depth.

Keywords: suspended water stop curtain; water inflow; Yangtze River floodplain; pressurized water

1   Introduction

With the rapid development of Chinese economy, various regions are vigorously developing underground space projects. With the continuous improvement of Chinese infrastructure technology, the number of large and deep foundation pits is also gradually increasing, accompanied by many difficulties[1]. The treatment of groundwater is the most critical step. The treatment of groundwater during the excavation process of foundation pits is mainly divided into water stopping and precipitation. The commonly used construction treatment method is the combination of suspended water stopping

curtains and precipitation wells to control groundwater. This combination method increases the length of the seepage path of groundwater flow into the precipitation wells, and there is continuous energy consumption during the process[2][3].Under the condition of suspended water stop curtain, the water inflow of the foundation pit is related to factors such as soil permeability coefficient, water level drop, radius of precipitation influence, excavation depth of the foundation pit, and the depth of the water stop curtain inserted into the bottom aquifer of the foundation pit[4]. At present, the design of suspended water stop curtains is mostly based on regional experience and the research on suspended water stop curtains mainly focuses on deriving theoretical formulas and studying seepage laws, lacking comprehensive analysis of various factors that affect water inflow[5]. Xiaowei Li[6] established a two-dimensional foundation pit plane model and a two-dimensional foundation pit seepage field model for the suspended water stop curtain with pressurized water. Through numerical calculation, the corresponding relationship between the two models was obtained and the formula for the water inflow per unit length of the foundation pit was obtained; Bereslavskii[7] based on fluid mechanics theory, applied conformal transformation method to solve the steady-state seepage problem under sheet piles in a plane, and compared the numerical calculation results to analyze the influence of various physical parameters of the model on the seepage characteristics; Miyake N[8] conducted multi aquifer pumping tests using multi screen pump wells and multi-stage pressure pipes based on a large foundation pit excavation project in Tokyo, Japan. The groundwater model was analyzed using finite element method, and the relationship between the length of the water stop curtain, pumping capacity, and the depth of the water level outside the curtain was obtained. Finally, the optimal length of the water stop curtain was determined; Lei Niu[9] used Mod-Flow software to obtain the variation law of the water inflow of the foundation pit with the insertion depth of the water stop curtain by changing the insertion depth of the water stop curtain; Hao Wang[10] derived the theoretical calculation formula for the water inflow of foundation pits under the conditions of confined aquifers and suspended water stop curtains and verified the feasibility of the theoretical calculation formula.

This article takes a foundation pit project in the water rich strata area of the Yangtze River floodplain as an example, and analyzes the factors affecting the water inflow of incomplete well foundation pits under pressure water conditions through numerical simulation, and obtains corresponding laws.

2   Numerical Analysis of Finite Element

2.1   Parameter Choice

A certain foundation pit project is located in the water rich strata area of the Yangtze River floodplain, with a total length of 5.4km for the main line. Construction section A (hereinafter referred to as the pressurized water section) is 1.2km long, with a excavation depth of 17m for the foundation pit, a water stop curtain insertion depth of 32m, and a water level drop of 1m to the bottom of the foundation pit. There is pressurized water distributed in round gravel, fine sand, and pebble mixed round gravel, with a pressurized water head of 63m. From top to bottom, the soil layers are: fill, muddy silty

clay, fine sand, pebble mixed round gravel, and round gravel. The parameters of each soil layer are shown in Table 1. In order to study the influence of a single factor on the seepage law, only one of the permeability coefficient k, the insertion depth L of the water stop curtain, the water level drop H, the influence radius R, and the excavation depth d of the foundation pit is changed. The permeability coefficient of the aquifer is taken as the mixed permeability coefficient, and the other parameters are the same as those in the previous construction section. The SEEP/W module in GeoStudio software is used to conduct numerical simulation calculation on the foundation pit to analyze the impact of the above influencing factors on the water inflow of the foundation pit.

Table 1.   Values of the construction section parameter of   Section A

Name	thickness (m)	unit weight (kN/m3)	permeability coefficient (m/d)
Banket	3	18.5	6
Silty Silty Clay	2	17.6	0.001
Silty fine sand	6	18.2	12
Pebble mixed with round gravel	6	20.5	20
Round gravel	47	20.5	16

2.2   The Establishment of Finite Element Model

A numerical model is established to analyze the changes in the water inflow of the foundation pit under different influencing factors in the confined water section, as shown in Figure 1.
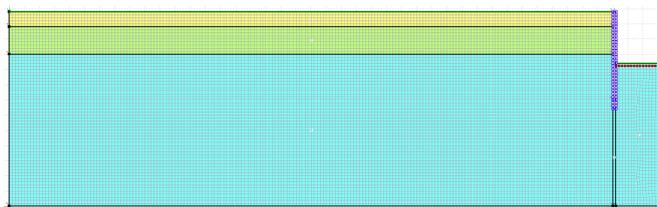

Fig. 1. Numerical model of confined water section

   The model simulates the working conditions of the excavation of the foundation pit to the bottom, dividing the grid in units of 1m, taking half of the excavation width of the foundation pit according to the principle of symmetry and simplifying the model establishment. The entire length of the pressurized water section model is 216m .The thickness is 64m. The excavation depth of the foundation pit is 17m.The influence radius is 200m. The insertion depth of the water stop curtain is 32m.The pressurized water head is given 63m at the left boundary. The pumping of pressure relief wells in the pit is reflected by assigning a total head of 46m boundary condition at a position 1m below the bottom of the pit.

3   Analysis of Computing Result

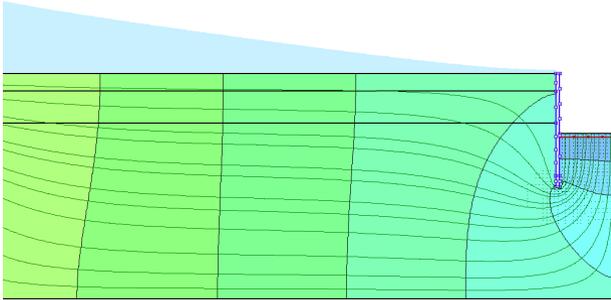After the calculation is completed, the seepage field of the confined water foundation pit is shown in the Figure 2.

Fig. 2. Schematic diagram of seepage of confined water

3.1   The Influence of Soil Permeability Coefficient K on Water Inflow

Based on a numerical model, the permeability coefficients k of the confined soil layer are taken as 46m/d,48m/d,50m/d,52m/d, 54m/d, 56m/d, 58m/d, and 60m/d, respectively. The variation curves of the unit flow rate at half width of the foundation pit with distance under different permeability coefficients are shown in Figure 3.

Fig. 3. The effect of soil permeability coefficient on water inflow

From Figure 3, it can be seen that when other parameters remain unchanged, for confined water, the amplitude of unit flow change gradually decreases as the distance

from the curtain increases and the water inflow of the foundation pit increases with the increase of soil permeability coefficient k, with a more significant increase.

3.2 The Influence of the Insertion Depth L of the Water Stop Curtain on the Water Inflow

Based on a numerical model, the depth L of the water stop curtain in the pressurized water section is taken as 28m,29m,30m, 31m, 32m, 34m, and 36m, respectively, to obtain the variation curve of the unit flow rate of the half width of the foundation pit with distance under different insertion depths of the water stop curtain, as shown in Figure 4.

Fig. 4. The effect of curtain depth on water inflow

As shown in Figure 4, when other parameters remain unchanged, there is an optimal insertion depth for the water stop curtain for confined water. When the water stop curtain is less than this depth, the water inflow of the foundation pit rapidly decreases with the increase of the insertion depth of the water stop curtain; When the water stop curtain is greater than this depth, the water inflow of the foundation pit slowly decreases with the increase of the insertion depth of the water stop curtain.

3.3 The Impact of Water Level Drop H on Water Inflow

Based on a numerical model, the water level drop H of the foundation pit in the confined water section is taken as 16.5m,17m,17.5m,18m,18.5m,19m,19.5m and 20m, respectively. The variation curve of the unit flow rate of the half width of the foundation pit with distance under different water level drops is shown in Figure 5.
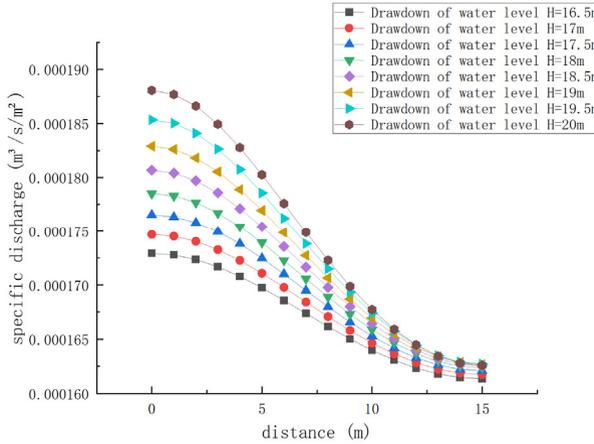
Fig. 5. The effect of water level reduction on water inflow in foundation pits

From Figure 5, it can be seen that when other parameters remain unchanged, for confined water, the amplitude of unit flow change gradually decreases as the distance from the curtain increases and the water inflow of the foundation pit increases with the increase of water level drop in the foundation pit.

3.4   The Impact of Radius R on Water Inflow

Based on the numerical model, the influence radii R in the confined water section are taken as 100m,125m,150m,175m,200m, 225m, 250m, 275mand 300m respectively and the variation curve of unit flow rate at half width of the foundation pit with distance under different influence radii is shown in Figure 6.
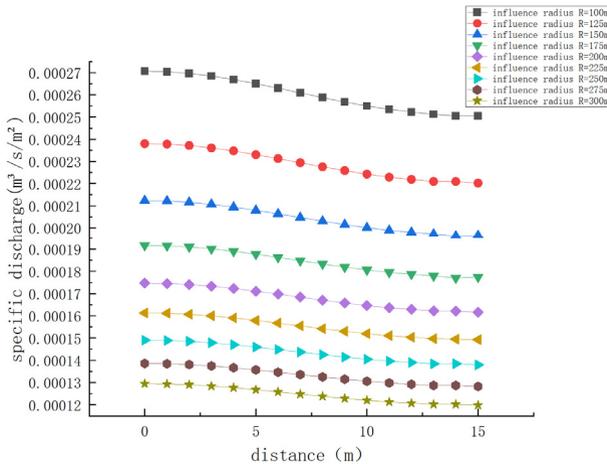

Fig. 6. The effect of radius of influence on water inflow

From Figure 6, it can be seen that when other parameters remain unchanged, for confined water, the change in unit flow rate gradually decreases and the decrease is not significant as the distance from the curtain increases. The water inflow decreases with the increase of the influence radius R.

3.5   The Influence of Excavation Depth D of Foundation Pit on Water Inflow

Based on a numerical model, the excavation depth d of the foundation pit in the confined water section is taken as 15m, 16m, 17m, 18m, 19m,20m and 21m respectively. The variation curve of the unit flow rate of the half width of the foundation pit with distance under different excavation depths is shown in Figure 7.
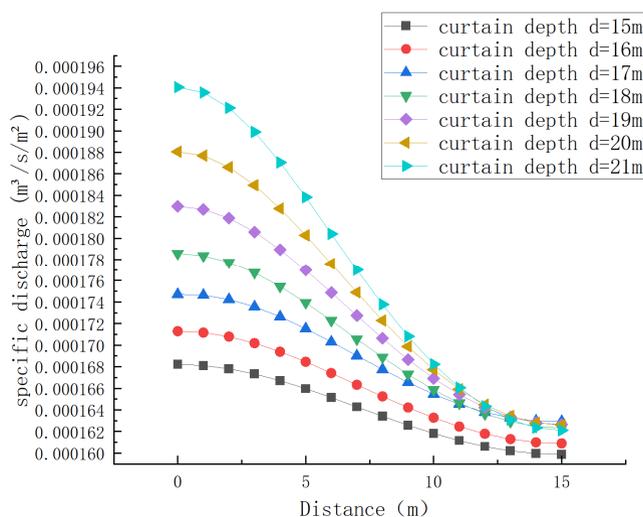

Fig. 7. The effect of depth of excavation of foundation pits in water inflow

From Figure 7, it can be seen that when other parameters remain unchanged, the amplitude of unit flow change gradually decreases with the distance from the curtain and the water inflow increases with the increase of excavation depth d.

4   Conclusions

Based on a certain foundation pit project in the water rich strata area of the Yangtze River floodplain, this article calculates the effects of five influencing factors, namely the permeability coefficient k, the insertion depth L of the water stop curtain, the water level drop H, the influence radius R, and the excavation depth d, on the water inflow of the foundation pit. The conclusion is as follows:

(1) The water inflow of the confined water is directly proportional to the permeability coefficient, decreasing with the increase of the water stop curtain depth, increasing

with the increase of the water level drop in the foundation pit, decreasing with the increase of the influence radius and increasing with the increase of the excavation depth of the foundation pit.

(2) As the distance from the curtain increases, the amplitude of unit flow change gradually decreases.

(3) It can be inferred from the influence of curtain depth L on water inflow that there exists an optimal insertion depth under each specific condition. Subsequently, detailed analysis can be conducted based on the actual geological and hydrogeological conditions of the construction site, taking into account the coupling effects of various influencing factors to obtain the optimal solution.

References

1. ZHANG Q, Song Y, Yan J.(2021)Numerical simulation and verification of water inflow of hanging water curtain. Geo-technical Engineering Technology,35(04):255-259.
2. Yu J.(2018) Analytical solution of steady flow seepage field of suspended water curtain foundation pit dewatering confined aquifer [D]. Tianjin university.DOI:10.27356/, dc nki. Gtjdu. 2018.001276.
3. Lin C, Li Q.(2022) Rich water sand metro station design of deep foundation pit precipitation and groundwater control research. Journal of heilongjiang traffic science and technology. The DOI: 10.16402 / j.carol carroll nki issn1008-3383.2022.03.041.
4. ZHAO Z. (2023)Design and research on dewatering scheme of deep foundation pit of subway station with rich water sand layer. New technology and new products in China. The DOI: 10.13612 / j.carol carroll nki CNTP. 2023.04.016.
5. HU H, Tian Wg, Zou X.(2023) Temporary dewatering well even in the land of rich water sand wall construction application. Journal of urban architecture. The DOI: 10.19892 / j.carol carroll nki CSJZ. 2023.10.48.
6. LI X.(2020)Hanging water stop curtain foundation pit precipitation water inflow research. The DOI: 10.27356 /, dc nki. Gtjdu..003714.
7. Bereslavskii E N. (2011)The flow of ground waters around a Zhukovskii sheet pile[J]. Journal of Applied Mathematics and Mechanics, 75(2):210-217.
8. Miyake N, Kohsaka N ,Ishikawa A.(2008) Multi-aquifer pumping test to determine cutoff wall length for groundwater flow control during site excavation in Tokyo, Japan[J]. Hydrogeology Journal, 16(5): 995–1001.
9. Niu L, Gahuang Y, Kong Y.(2023) Analysis of dewatering seepage in suspended water curtain foundation pit of water-rich sand layer.Tianjin Construction Science and Technology,33(02):52-54.
10. Wang H, LIU Y, Zhao Y.(2022) Mounted under the condition of water stop curtain foundation pit water inflow computing research.DOI: 10.13578/j.carol carroll nki.