Study on The Influence of Enclosed Cut-off Walls on Precipitation Design for Foundation Pit Engineering

Lianxiang Li\textsuperscript{1,2,a}, Fenting Lu\textsuperscript{1,2,b}, Zongcai Li\textsuperscript{3}

\textsuperscript{1}China Engineering Research Center of Foundation Pit and Deep Foundation, Shandong University, Jinan 250061, China

\textsuperscript{2}School of Civil Engineering, Shandong University, Jinan, Shandong 250061, China

\textsuperscript{3}Jinan Construction Engineering Quality and Safety Supervision Station, Jinan, Shandong 250014, China

\textsuperscript{a}jk_doctor@163.com

\textsuperscript{b}tiffinylu@163.com

Keywords: cut-off wall; drawdown; numerical simulation

Abstract. The current design specifications ignore the influence of cut-off walls on foundation pit de-watering design, the calculation formula of water inflow and the predictor formula of drawdown for enclosed cut-off walls insert into impermeable layer and enclosed cut-off walls insert into aquifer layer are presented. With an actual project, the calculated methods are verified feasibly by comparing the calculated result with numerical simulation result and the measured result, providing guidance for engineering precipitation design.

Introduction

Technologies about foundation pit de-watering are developing rapidly, and are increasingly focusing on the environment. So cut-off walls are more and more introduced into engineering precipitation to control the impact of de-watering on the surrounding environment. If the location of foundation pit is closed to the surrounding buildings or structures, while the water level needed to be lowered is high and the thickness of the aquifer is relatively small, enclosed cut-off walls inserting into impermeable layer can be set all around the foundation pit to avoid the harmful effect of differential ground settlement caused by precipitation on the surrounding buildings and underground pipelines. Enclosed cut-off walls inserting into impermeable layer can block the hydraulic connection between the inside and the outside of the foundation pit, ensure the water level requirement inside the foundation pit and keep the water level outside the foundation pit unchanged, as shown in Figure 1. When the water level is high and the thickness of the aquifer is relatively big, considering the difficulty of construction and economy, enclosed cut-off walls inserting into aquifer layer can be set all around the foundation pit by coordinating with recharge to reducing the drawdown outside the foundation pit, as shown in Figure 2.

Cut-off walls can reduce the water inflow, which not only meet the precipitation needs, but also reduce the number of de-watering wells by comparing to traditional foundation pit de-watering design. Therefore, for the foundation pit with cut-off walls, the water inflow should be accurately calculated. In recent years, lots of literature analyzed the influence of cut-off wall on engineering precipitation through theoretical derivation, numerical simulation, experimental research and other methods[1-3]. Combined with previous studies, the water inflow calculation method for the foundation pit with enclosed cut-off wall was presented, and was proved feasible by comparing to simulated results and measured results.

Precipitation design method of the foundation pit with enclosed cut-off walls

According to the book, The manual of foundation pit dewatering[4], the way to determine the impact of cut-off walls is as follows: if the depth of cut-off walls inserting into aquifer layer is less than 3 ~ 6m, and is less than 20 % ~ 30% of aquifer thickness, the influence of cut-off walls on
seepage field can be ignored when group wells working; if the depth of cut-off walls inserting into aquifer layer is 10~15m or more than 15m, or about 30%~80% of aquifer thickness, the influence of cut-off walls on seepage field should not be ignored when group wells working.

Building
Cut-off wall
De-watering well
Pipeline
Fig. 1 Enclosed cut-off walls insert into impermeable layer

Building
Recharge well
Cut-off wall
De-watering well
Pipeline
Fig. 2 Enclosed cut-off walls insert into aquifer layer

(1) When the curtain is inserting into impermeable layer, the entire pit can be seen as a big vat, the water in the bucket should be reduced to the required level, and the wells inside the pit are fully penetrating wells. The total inflow can be calculated as:

For unconfined water: \[ Q = \frac{\mu F s}{t} \]  
For confined water: \[ Q = \frac{F s (0.05 \sim 0.1) W}{t} \]

where, \( Q \) is the water inflow, \( F \) is the plane area rounded by cut-off wall, \( s \) is the design drawdown, \( t \) is pre-pumping time, \( \mu \) is the specific yield of unconfined aquifer, \( s_c \) is the distance from the roof of confined aquifer to the design water level, \( W \) is the original natural moisture content.

When the pumping time is long enough \((t \equiv (0.1 \sim 0.2)r^2/\alpha)\), the drawdown inside the pit can be predicted by the following formula:

For unconfined water: \[ s_0 = H - \sqrt{H^2 - \frac{Q \alpha}{2 \pi k r^2} - \sum_{i=1}^{n} \frac{q_i \ln \frac{r}{r K r_i}}{\frac{r}{r K r_i}}} \]

For confined water: \[ s_0 = \frac{Q}{\pi k M r^2} + \sum_{i=1}^{n} \frac{q_i \ln \frac{r}{r K r_i}}{\frac{r}{r K r_i}} \]

(2) When the curtain is inserting into aquifer layer, the entire pit also can be seen as a big vat, but the water needed be draw out contains the water in the bucket and the water infiltrating from the bottom of the bucket. The total inflow are the sum of the water field inside the pit and the water flow from the outside of the pit, which can be calculated as follows [5]:

\[ Q = Q_I + Q_o \]
\[ Q_o = k B s \frac{l}{b + H_w + T_m} \]

where, \( Q_I \) can be calculated by Eq.1~2, \( B \) is the perimeter rounded by cut-off walls, \( l \) is the distance from the bottom of cut-off walls to the impermeable layer, \( H_w \) is the rest water level outside the pit, \( T_m \) is the distance from the bottom of cut-off walls to the designed water level.
The water level inside the pit water table can be calculated by Eq.3~4, where the total inflow $Q$ should be calculated by Eq.5. By assuming that the whole foundation pit is a big well and the cut-off wall is the wall of the well, the water level outside the pit can be calculated as follows:

For unconfined water:  
$$s_0 = H - \sqrt{H^2 - \sum_{i=1}^{n} \frac{d_i}{\pi k} \ln(1.27 \frac{R}{r_i})}$$  
(6)

For confined water:  
$$s_0 = \sum_{i=1}^{n} \frac{d_i}{2\pi kl} (1.27 \frac{R}{r_i})$$  
(7)

where, $R$ is the influence radius of precipitation.

**Case verification**

The dewatering well layout chart and precipitation profile of a foundation pit are respectively shown in Figure 3 and Figure 4 [6]. The average permeability coefficient is 0.52 m/d, and enclosed cut-off walls inserting into aquifer layer were set around the pit. In order to verify the calculation methods described herein, comparing the calculated result of the water level outside the pit after 25 days of precipitation to the simulated result and the measured result.

The specific yield $\mu$ was valued as 0.08, and taking all parameters into above equations:

$$Q_I = 0.085 \times 3.14 \times 29.6^2 \times 25 + 25 = 233.85 (m^3/d)$$  
$$Q_O = \frac{0.52 \times 2 \times 3.14 \times 30.4 \times 25 \times 3.5}{0.8 + 37.4 + 8.9} = 184.43 (m^3/d)$$

Each well had same flow, then:

$$q_i = \frac{Q_I + Q_O}{6} = \frac{233.85 + 184.43}{6} = 69.7 (m^3/d)$$

Substituting $q_i$ into Eq.6, to calculated the drawdown at 0m, 5m, 10m, 15m, 30m, 50m, 100m, 150m and 200m away from the cut-off wall.
The pore water pressure after 25 days of precipitation with and without cut-off walls calculated by finite element software are shown in Figure 5 and Figure 6. Plotting the drawdown curves of calculated result, simulated result and measured result in Figure 7.

As can be seen from Figure 7, cut-off walls effectively reduce the drawdown outside the pit, the calculated result is basically the same with the simulated result, where the maximum error is 13% and occurs on the edge of cut-off wall, and the calculated result is a little less than the measured result, where the maximum error is approximately 14%.

Fig. 7 Comparison chart of dropdown outside the cut-off wall

**Conclusion**

(1) According to the existing form of cut-off walls, the calculation formula of water inflow and the predictor formula of drawdown for enclosed cut-off walls insert into impermeable layer and enclosed cut-off walls insert into aquifer layer are respectively presented.

(2) The numerical simulation results vividly demonstrate the impact of cut-off walls on groundwater seepage, and confirm that the precipitation design cannot ignore the impact of cut-off walls.

(3) By comparing the calculated result to the simulated result and the measured result, verifying that the calculation method of precipitation in this paper is simple and feasible, and can be used in the actual project.

**Acknowledgements**

This work was finally supported by National Natural Science Foundation of China (51479107) and Science and Technology Plan Project of Jinan City (201201145).

**Reference**


