

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

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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.

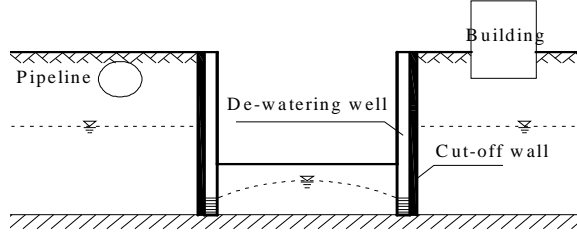


Fig. 1 Enclosed cut-off walls insert into impermeable layer

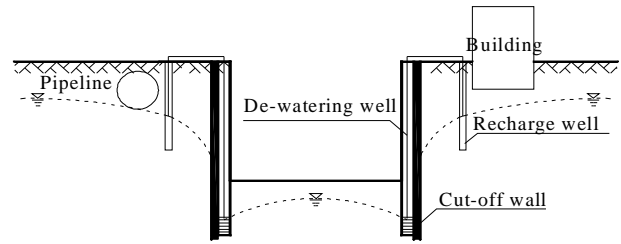


Fig. 2 Enclosed cut-off walls insert into aquifer layer

(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:

$$\text{For unconfined water: } Q = \frac{mFs}{t} \quad (1)$$

$$\text{For confined water: } Q = \frac{Fs_c(0.05 \sim 0.1)W}{t} \quad (2)$$

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, μ 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 ($t \gg (0.1 \sim 0.2)r^2/\alpha$), the drawdown inside the pit can be predicted by the following formula:

$$\text{For unconfined water: } s_0 = H - \sqrt{H^2 - \frac{Q}{2pk} \frac{at}{r^2} - \sum_{i=1}^n \frac{q_i}{pk} \ln \frac{r}{r_K r_i}} \quad (3)$$

$$\text{For confined water: } s_0 = \frac{Q}{pkM} \frac{at}{r^2} + \sum_{i=1}^n \frac{q_i}{2pkM} \ln \frac{r}{r_K r_i} \quad (4)$$

where, s_0 is the drawdown at any point inside the pit, H is the thickness of unconfined aquifer, M is the thickness of confined aquifer, k is the permeability coefficient, α is the pressure conductivity, r_K is a coefficient which can be looked up on some relevant literature, r is the equivalent radius of the pit, q_i is the water yield of the i -th well, r_i is distance from the i -th well to any point inside the pit, n is the number of de-watering well.

(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]:

$$Q = Q_I + Q_O \quad Q_O = kBs \frac{l}{b + H_w + T_m} \quad (5)$$

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:

$$\text{For unconfined water: } s_0 = H - \sqrt{H^2 - \sum_{i=1}^n \frac{q_i}{pk} \ln(1.27 \frac{R}{r_i})} \quad (6)$$

$$\text{For confined water: } s_0 = \sum_{i=1}^n \frac{q_i}{2pkl} (1.27 \frac{R}{r_i}) \quad (7)$$

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.

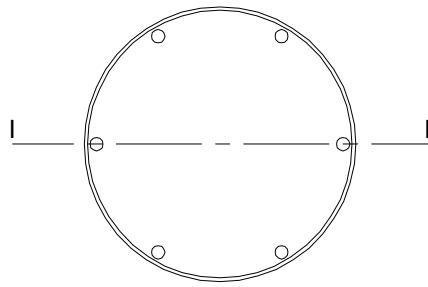


Fig. 3 Pipe well layout chart

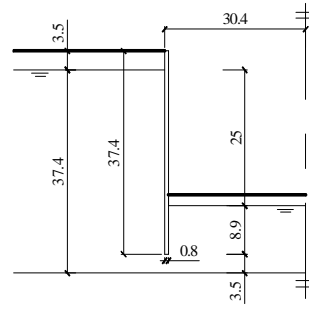


Fig. 4 Precipitation profile

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

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

Each well had same flow, then:

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

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.

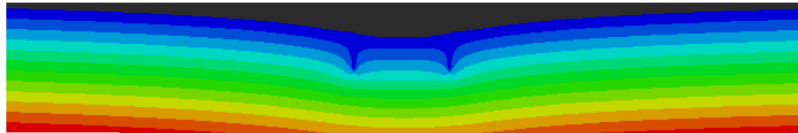


Fig.5 Contours of pore water pressure without cut-off wall

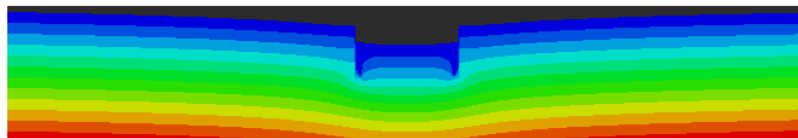


Fig.6 Contours of pore water pressure with cut-off wall

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%.

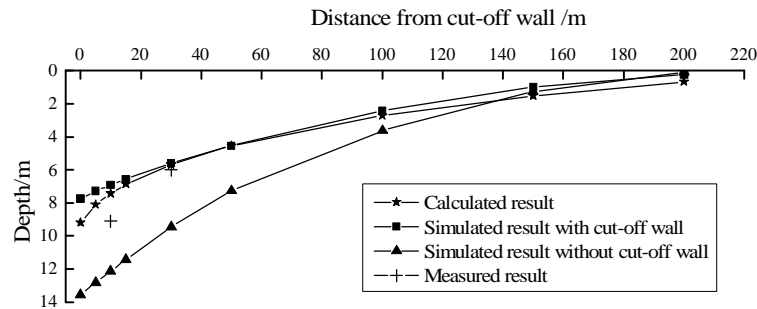


Fig. 7 Comparison chart of dropdown outside the cut-off wall

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.

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