# Analysis of Groundwater Seepage State of Foundation Pit with Pensile Cut-off Curtain

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**Abstract.** Accurate description of seepage state is the basis and premise for foundation pit groundwater control design. The water level inside and outside the foundation pit and the pore water pressure of the surrounding soil, and the rate of water inflow of foundation pit with suspended water curtain are analyzed in this paper based on the measured data. The determination of dewatering target layer and the change law of water head and pore water pressure during precipitation are summarized. It is hoped that the analysis of the successful case of groundwater control will be of some reference value to similar projects.

## Introduction

Pensile cut-off curtain is generally used in foundation pit site with large thickness of aquifer and relatively low requirement of surrounding environment. In recent years, the comprehensive advantages of pensile cut-off curtain in the economic, quality, safety and other aspects have been proved in many cities [1, 2]. The application of pensile cut-off curtain is gradually changed from "helpless adoption" to "active adoption" which can save the project cost and reduce the adverse influence on the initial seepage state of groundwater".

In the construction of urban rail transit, it is common to use the ground connecting wall as the soil retaining curtain and the water retaining curtain. But the required depth of the soil retaining curtain is often inconsistent with the water retaining curtain. Generally speaking, the requirement of the soil retaining must be satisfied, while the requiring depth of the water curtain can sometimes be neglected or accommodated, which greatly increases the risk of groundwater control in the foundation pit. The failure cases clearly reveal that the problems caused by improper groundwater control measures is far more than foundation pit ponding. When groundwater flows around the bottom of the curtain into the pit, it is possible to cause the whole disturbance to the foundation under the influence of the seepage force. Then the safety of the whole enclosure structure would be threatened, and the settlement around the foundation pit would be increased. Therefore, groundwater control is particularly critical for the foundation pit with pensile cut-off curtain, And the accurate description of seepage state of foundation pit is the basis and premise for making reasonable groundwater control plan of foundation pit.

Many scholars have carried on the thorough practice and research to the ground water seepage law of the foundation pit with pensile cut-off curtain and the influence of the foundation pit dewatering on the stability of the foundation pit through the model test and numerical simulation [3, 4, 5, 6, 7]. This paper took sports park station foundation pit project of Harbin Metro Line 3 as the background, the seepage state including monitoring data of flow rate, artesian water head and pore water pressure of groundwater inside and outside of pit during the construction of foundation pit is analyzed. It is expected to be of reference significance to the ground water control of the foundation pit with pensile cut-off curtain.

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## General situation of Engineering

The Sports Park Station of Harbin rail transit line 3 is a 2 stories underground station. The excavation depth of the foundation pit is 17.2 m~20.1 m. The 800mm thick diaphragm wall was designed to retaining both soil and water, the pensile curtain wall was applied in the west of the foundation pit, set the depth to 37 m, while in other areas, set the wall depth to 47 m. The floor plan of the water curtain of the foundation pit is shown in figure 1.

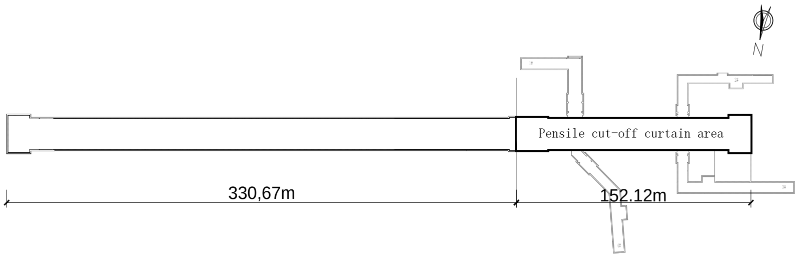


Fig.1 Sketch map of the foundation pit

The site of the station belongs to the floodplain geomorphic units of the Songhua River. The alluvial plain facies and quaternary Holocene natural sedimentary soil are widely distributed in the site. The formation lithology of the site is mainly filled with silt, silty clay and sandy soil, and the groundwater involved in excavation is mainly Quaternary unconsolidated rock pore water. There is a certain hydraulic connection between the upper and lower aquifers in the field, and the bedrock is deep buried, which is very representative in the locality.

The bottom of the foundation pit is located in 2-4 layers of medium coarse sand and locally enters the silty clay layer of the 2-4-1 layer. The design of groundwater control mainly considers the risk of inrush from the lower 7-2 aquifer, and the safety coefficient of the anti-uprush stability of the foundation pit of the 7-2 confined aquifer is between 0.748~1.98. There are 37 geological drilling holes in the site, of which 81.1% of the drilling rate does not meet the requirements of calculation, and there is a great risk of inrush in the foundation pit.

Considering the site formation conditions and distribution of groundwater and the curtain insertion depth and other factors, well dewatering is chosen for the water control method to this pit. The layout of foundation pit dewatering is shown in figure 2.

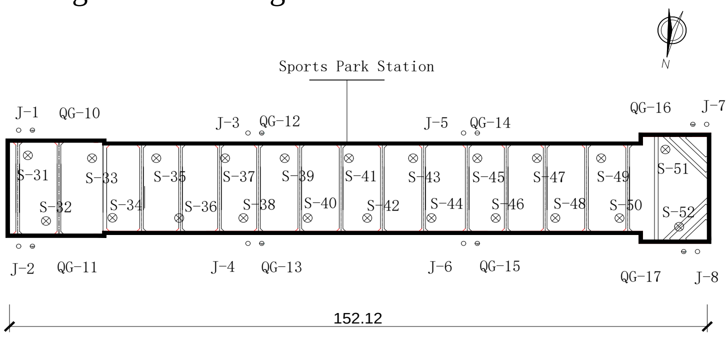


Fig.2 Plane layout of foundation pit dewatering

## Field measurement of groundwater seepage

**Water inflow of foundation pit.** In order to make the water level below the excavation surface, the precipitation in the pit is operated on a batch basis. With the excavation of the foundation pit, the precipitation area is gradually moving eastward, the number of synchronized dewatering wells is controlled at about 10. In the excavation stage, the total water yield and the change of the average water level in the pit are shown in figure 3.

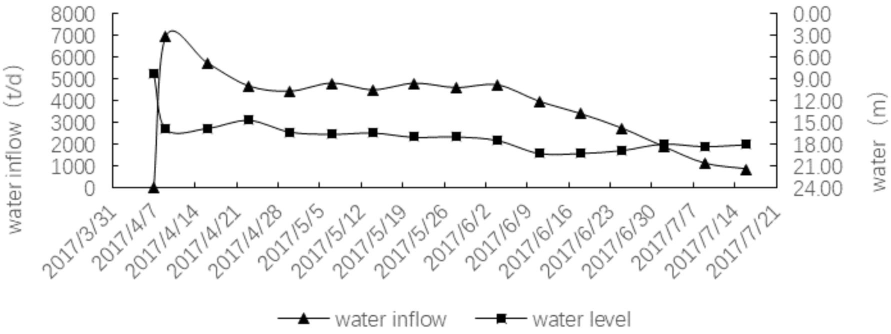


Fig.3 Time history curve of water level and water inflow of the foundation pit

As shown in Figure 3, the amount of water at the early stage of the excavation is very large, After the number of operation well reaches 10, the average water yield of single well is about 30 t/h. The watery and permeability of overlying phreatic aquifer is the main reason for the large amount of water gushing in the foundation pit at the earlier stage, and the existence of the curtain leads to the gradual decrease of the water yield. After two weeks of dewatering, the water level in the foundation pit is basically stable, when the overall water level of the foundation pit reaches the excavation face, the water yield of the foundation pit is basically stable at about 4600 $m^3$/d. The water flow in this stage mainly comes from flow around the curtain and flow of the lower lying confined water, it is not in fact precipitation in this stage, but more indirect pressure-reduction of the lower lying confined aquifer.

**Pore water pressure of soil around the foundation pit.** Pore water pressure is an important index to describe the seepage state of groundwater. According to the principle of effective stress, the dissipation of pore water pressure is the direct cause of soil settlement. In a steady seepage field, the pore water pressure is approximately equal to hydrostatic pressure, so the pore water pressure can indirectly reflect the height of groundwater head of the measuring point. 3 pore water pressure measurement groups are arranged outside the foundation pit, and each group is composed of 4 or 5 measuring points of different depths. Among them, the test group 1 is located in the northwest side of the deep excavation, consisting of 4 measuring points, and the buried depth is 10 m, 20 m, 34 m and 40 m respectively. The variation of the pore water pressure at each test point of group 1 during the dewatering stage of the foundation pit is shown in figure 4~7.

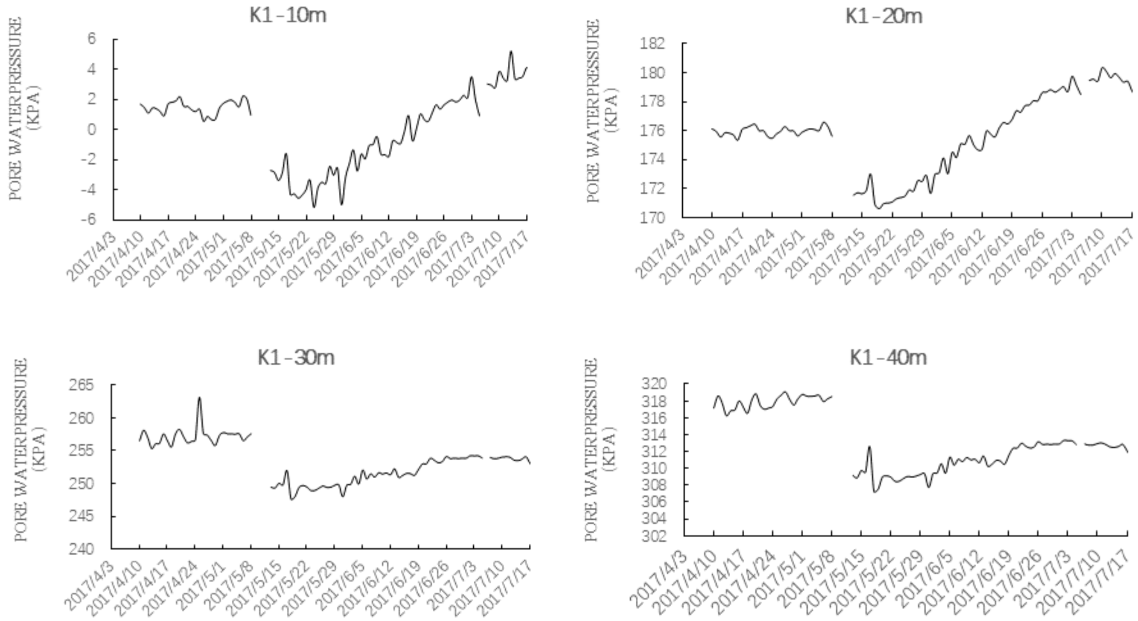


Fig.4 Duration curve of pore water pressure

The curve shows that the measured values of pore water pressure have an obvious stage of decline and rise. The basic law revealed is that the pore water pressure drops immediately after the dewatering of foundation pit and the unloading of soil excavation, and rises after the construction of the main structure. After the decline of pore water pressure, the recovery rate is relatively slow, but the magnitude of recovery is greater than the magnitude of decline, and the maximum value of pore water pressure after recovery exceeds the initial value. The main causes of this phenomenon are the following: 1） The strong permeability of the aquifer leads to a relatively fast rate of decrease in pore water pressure; 2） the pore water pressure at the measuring point changes from the pore water pressure to the seepage pore water pressure during the process of the surrounding groundwater flowing into the foundation pit, in this coarse-grained stratum, the influence range of precipitation is relatively wide, and the balance of water head gradient or water seepage pressure difference needs a relatively long time.

The measuring point K1-30m and K1-40m are closer to the curtain bottom (37 m), and the change is similar to the general trend of the two measuring points in the shallow layer: there are also obvious decline, and the decline is up to 11.3 kPa (K1-40 m), the decrease is slightly larger than the measure point in shallow layer. The difference is that the rate and amplitude of pore water pressure recovery at deep test points are obviously smaller than that of shallow layer, and after the rebound, the maximum values are below the initial value.

**Confined water head outside of the foundation pit.** During the process of dewatering, the water level changes of each aquifer are monitored closely in real time. According to the change of water level, the running time and the precipitation amplitude of each dewatering well are adjusted to ensure the water level to meet the needs of the construction of the pit and minimize the adverse impact on the surrounding environment. In the construction stage of large mileage part of foundation pit, the variation trend of water head in the deep groundwater first decreases and then slowly picks up. The relative large variation was occurs at J5~J8, the cumulative maximum value of drawdown was 1.82m (J5), and the minimum value was 1.21m (J4), while the average value of 1.42m. During the dewatering period, the pressure water level observation well J8 and the pore water pressure measurement group 1 are the most recent, and its water head changes are shown in Figure 7.

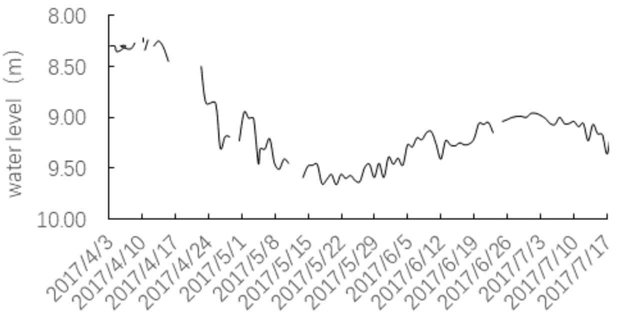


Fig.5 Curves of the variation of deep water level around the pit during construction period

As shown in Figure 5, the variation trend of confined water head is similar to the pore water pressure in corresponding layer. In the early stage, the decrease of confined water head was about 1.4 m, while the pore water pressure decreased by 11.3 kPa, and the pore water pressure was converted into water head, and the difference between them was about 0.25 m. The trend of water head recovery is basically the same as that of deep pore water pressure, the recovery is also slow and the recovery amplitude is relatively small, and the maxima is less than the initial value.

## Summary

The measured data of the water inflow, the confined water head and the pore water pressure reflect the seepage of the foundation pit relatively comprehensively. Through the analysis of the measured data, the following conclusions can be obtained:

(1) As to the foundation pit with pensile cut-off curtain, the water inflow mainly comes from the water outside the foundation pit, the dewatering of upper aquifer is also the indirect decompression of subjacent confined aquifer, and the reduced amplitude depends on the aquitard vertical permeability.
(2) The barrier effect of pensile cut-off curtain to flow around the foundation pit is not instantaneous, but will make the seepage to reach a new balance. At least on the scale of time of the construction, the barrier effect on foundation pit seepage is very obvious.

In the design of suspended foundation pit dewatering, the water inflow around the pit should be calculated as the main factor of the total water inflow volume. Generally, the dewatering of upper aquifer and decompression of subjacent confined aquifer are a mixed process. The main dewatering stage is to make the water inflow from aquifer outside of foundation pit and the water inflow from the lower confined aquifer reach the balance of the water pumping volume of the foundation pit.

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