Seepage analysis on Pensile curtain in pumping groundwater of foundation pit in the water-rich sand in Harbin floodplain

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Abstract. Setting the impervious curtain can reduce the effect of pumping groundwater in the pit on the groundwater level outside the pit and the impact of excavation on the surrounding environment. The descent of the groundwater level in the pit is closely related to the depth of the impervious curtain. This paper, with simulate computation and quantitative calculation, analyses the relationship between the depth of the impervious curtain and the depth of the head. The simulation results show that with the increase in the depth of the curtain, the influence of pumping groundwater on the pit is reduced. This process is very significant at the beginning. But when the length of the impervious curtain increases to a certain value, it will no longer have obvious influence on the decline in the water level outside the pit. While at the same time, the project cost is significantly increased. Through this comparative analysis, it is clarified that the application of pensile curtain is feasible in Harbin floodplain area, which provides effective reference to the application of pensile curtain in the Harbin River floodplain.

1. Introduction

The floodplain formation in Songhua River, Harbin, is a typical two-element structure. The stratum is characterized by strong water permeability and strong hydraulic connection between groundwater and Songhua River. It is difficult and risky to dig deep foundation pit. At present, the impervious curtain of foundation pit in Harbin area is often filled with mudstone. In theory, this will cut off the upper confined aquifer. However, the problems brought about are the high project cost, long construction cycle and the destruction of the underground ecological environment.

On the premise of ensuring safety, the application of the pensile curtain can greatly reduce the project cost, shorten the construction period, avoid waste of resources and damage to the ecological environment of groundwater in the floodplain area of Songhua River [1].

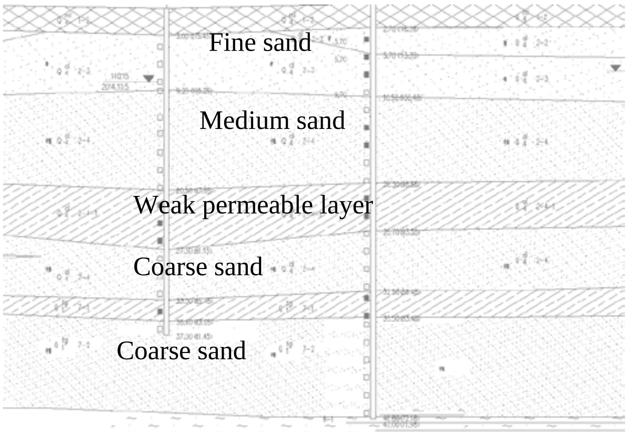

Fig. 1 Illustration of Typical Binary Stratigraphic Structure of Harbin River Floodplain

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Right now, there are already mature experiences in the vast application of pensile curtain for retaining structure of deep foundation pit in the subway projects of rich water area like domestic Yangtze River Delta and Pearl River Delta area. This article, based on the construction of Sports Park station of Harbin Metro line 3, studies the application of pensile curtain. Using three-dimensional seepage software ModFlow, it calculates the influence of the foundation pit dewatering project on surrounding environment when setting different depth of the impervious curtain.

2. Project Overview

The distance between the nearby buildings and the foundation pit is more than 2 times the depth of the foundation pit. The station is 482.0m in length. Its standard section is 19.7m in width. The depth of the station is about 17.5m ~20.45m. The bottom of the foundation pit is mostly in the middle coarse sand (2-4) layer, and part is in the silty clay (2-4-1) layer.

3. Engineering Geology and Hydrogeological Conditions

According to the regional geological data and the survey, the geomorphic unit of the project belongs to the low floodplain of Songhua River.

There are two kinds of groundwater in this project: phreatic water and pore confined water.

3.1 Phreatic Water

It mainly occurs in the sand layer of Quaternary Holocene. The stratum is rich in water and has strong permeability. It has close hydraulic contact with Songhua River and HeJiaGou. The total thickness of the aquifer is 20~30m. Its main recharge sources are lateral runoff recharge of Songhua River and infiltration recharge of HeJiaGou. The discharge system mainly includes evaporation and artificial exploitation. The annual groundwater level varies from 2 to 3m.

3.2 Confined Water

The first layer of confined water mainly occurs in 2-4 layers of medium coarse sand. The second layer of confined water mainly occurs in the sand of the ice accumulation layer which belongs to the lower Pleistocene Deep East formation of Quaternary System, the roof of which is 7-1 layer of cohesive soil, and the bottom is silty mudstone of the lower Cretaceous. The aquifer thickness is about 9~15m. Due to the partial absence of the7-1 layer, the aquifer has no stable water resisting layer, and is partly connected to the upper aquifer, with slight pressure. During the survey period, the head of confined water was about 30m. The aquifer has strong permeability and large water content.

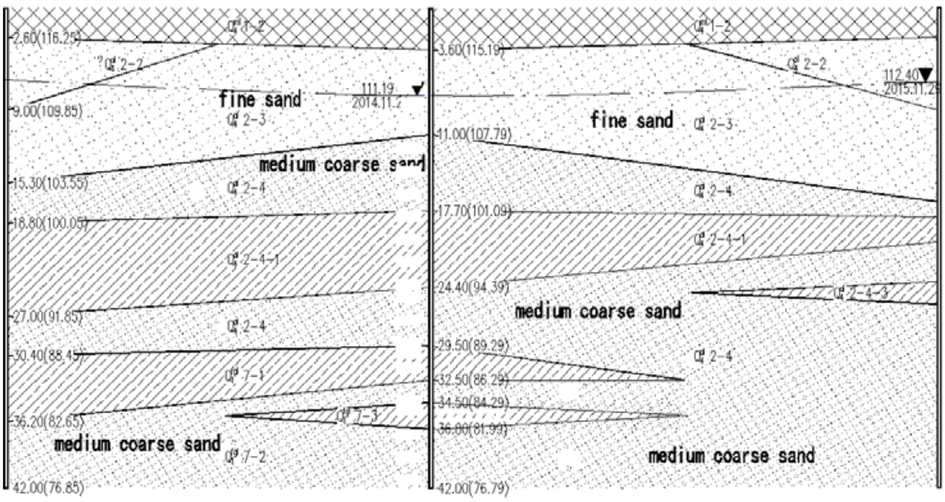


Fig. 2 Schematic diagram of hydrogeological features

4. Pumping Test

A special hydrogeological pumping test has been carried out, and the hydrogeological parameters of each aquifer and the weak permeable layer have been obtained. Details are shown in Table 1.

Table 1 A list of hydrogeological parameters obtained from pumping tests

layer	Kh(m⁄d)	Kv(m⁄d)
2-3	33	3
2-4	39	5
7-2	17	2
2-4-1	0.3	0.1
7-1	0.1	0.05

5. Analysis of Groundwater Risk

The first confined aquifer the 2-4 sand layer and the second confined aquifer the 7-2 sand layer exist at the bottom of the foundation pit. The stability calculation of the foundation pit should be carried out. Through the calculation of the risk of the first confined aquifer, the minimum of the safety factor (Fs) is 0.09, when the foundation pit is excavated to the base, the maximum drawdown is 15.5m, the drawdown is very large, and the risk of pumping groundwater is very high. At the same time, considering the bottom depth of 2-4 layer is 24.9~33m, and the diaphragm wall is calculated with the minimum depth of 30m. Comprehensive consideration, the diaphragm wall cuts through the first confined aquifer (2-4).

Through the calculation of the risk of the second confined aquifer(7-2), The minimum of the safety factor(Fs) is 0.75, when the foundation pit is excavated to the base, the maximum drawdown is 7.8m.

Combined with the calculation results and stratum distribution, it is considered that the project has the construction condition of pensile curtain, and it can make full use of the weak permeability of 7-1 layer and the low risk of second confined aquifer(7-2) with the lower drawdown can meet the safety requirements.

Based on the above analysis, it is considered that the pensile curtain and pumping groundwater from foundation pit can be used to solve the problems of groundwater in engineering.

6. Selection of impervious curtain

Combined with the excavation depth of foundation pit, the foundation pit bracing design institution claims that the minimum depth of diaphragm wall is 32m by force calculation. Therefore, the minimum depth of the simulation is 32m. In the light of experience of similar projects in Harbin, the diaphragm wall of the project needs to be set up 47m and the bottom of the wall needs to insert into the 8-1 layer of mudstone. According to the risk analysis of the project, the diaphragm wall is set for the 7-2 layer with the pensile type. The initial depth is 37m, based on which, the pensile curtain is divided into 0m, 32m, 37 and 47m to calculate the seepage of the groundwater and evaluate the different influences of pumping groundwater inside the pit on groundwater outside [3].

7. Calculation Model

7.1. Boundary Condition

In the horizontal direction, in order to make the pumping groundwater of the foundation pit have no influence on the water level of boundary, the study area is extended outwards. The horizontal lateral boundary is taken as the first boundary condition. On the vertical, the depth reaches 4m below the top of mudstone layer, and the total formation thickness is 49m. The drainage term is mainly the pumping well arranged in the foundation pit. According to hydrogeological conditions and engineering geological conditions, the simulation range is extended in four directions, outside the pit, to 500m. [2]

7.2. Calculation Parameters

Table 2 Model layers of parameters

Layer	T (m2/d)	Kh(m⁄d)	Kv(m⁄d)	Ss
2-3	396	33	3	2.12e-3
2-4	156	39	5	3.39e-2
7-2	136	17	2	2.01e-4
2-4-1	1.2	0.3	0.1	0.0001
7-1	0.75	0.1	0.05	0.0001

7.3. Setting up of impervious curtain

The impervious curtain is divided into four depths, 0m、 32m、 37m and 47m, as shown below.

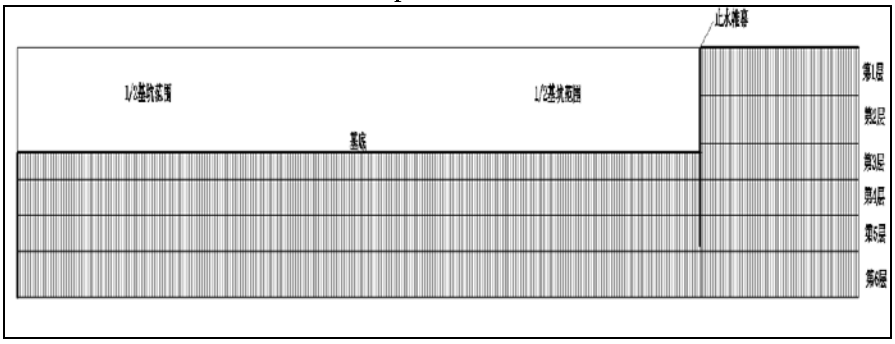


Fig. 3 Schematic view of the depth profile of the 37m long water curtain

7.4. Pumping well layout

The depth of the pumping well is about 6m below the base, and the depth of the pumping wells is 26m. Under the different depths of impervious curtain, the number of pumping wells is 44, and the output of single well is different.

8. Comparison and Analysis of Calculation Results

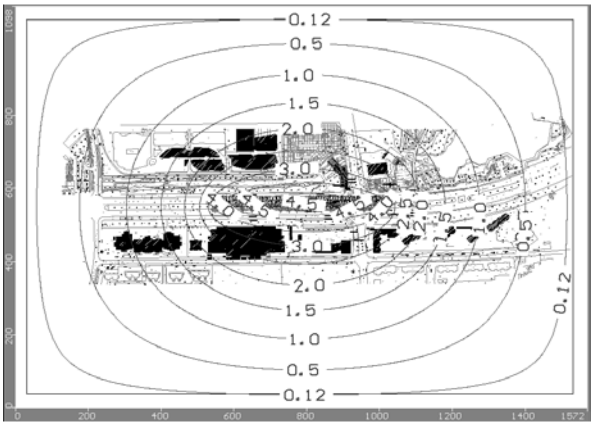
Through the simulation calculation, under the different depths of impervious curtain, the results are listed as follows.

Table 3 List of Simulation Results

Depth of impervious curtain (m)	well yield (m^3/d)	Well Number	7 days later, drawdown in pit	60 days later, drawdown outside pit
0m	2400	44	4.5m	4.5m
32m	1680	44	7m	9m
37m	480	44	18m	21m
47m	240	44	18m	25m

Note: 1. in all cases, the use of a unified well depth (26m)
2. Adopt unified hydrogeological parameters
3.under different depths of curtain, the output of a single well is not the same, but the effect of dewatering in the pit requires the same. [4-6]

At different depths of impervious curtain, after pumping for 60 days, the water level contours inside and outside the pit are as follows:



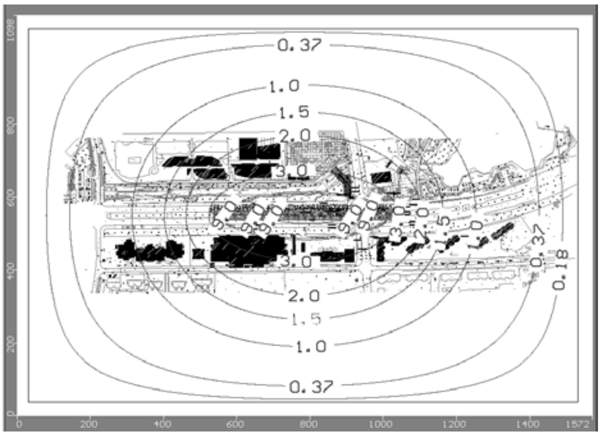
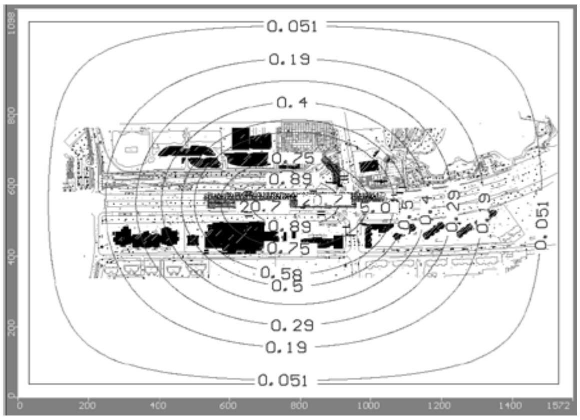


Figure 4. Contour without impervious curtain **Figure 5.** Contour of the 32m-impervious curtain



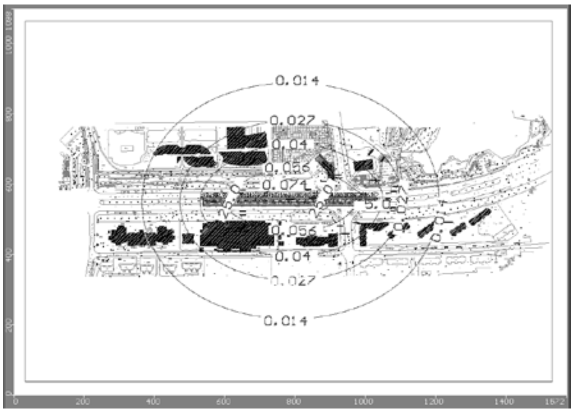


Figure 6. Contour of 37m-impervious curtain **Figure 7.** Contour of 47m-impervious curtain

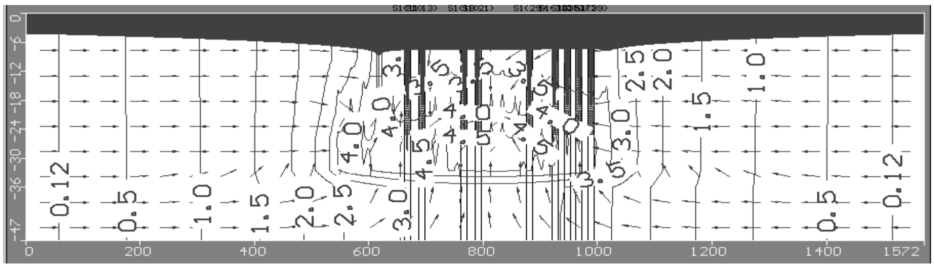


Figure 8. Seepage path profile without impervious curtain

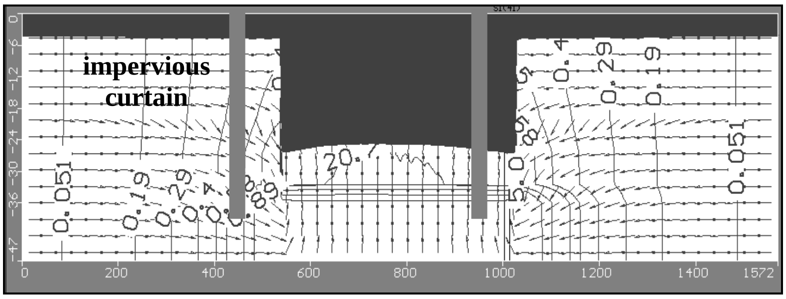


Figure 9. Seepage path profile of the 37m-impervious curtain

It can be clearly seen from the pictures above that 0m-impervious curtain and 32m-impervious curtain are not cut through the confined aquifer. In the case of the 0m-impervious curtain, according to100m^3/h -discharge rate of single well, the drawdown in the pit is only 4.5m after 60 days' pumping; in the case of the 32m- impervious curtain, according to 70m^3/h-discharge rate of single well, the drawdown in the pit is only 9m after 60 days' pumping. None of the two conditions meets the requirements of drawdown for pit excavation. Meanwhile, due to large amount of horizontal recharge and leakage recharge outside the pit, the groundwater pumping in the pit has a great impact on the environment outside of the pit.

The 37m and 47m impervious curtain cut off the upper Phreatic aquifer and the first confined aquifer. In the case of the 37m-impervious curtain, with 20m^3/h-discharge rate of single well, the drawdown in the pit meets the requirements of safety excavation after 7 days' pumping. In the case of the 47m- impervious curtain, with10m^3/h-discharge rate of single well, the drawdown in the pit meets the requirements of safety excavation after 7 days' pumping. At the same time, through the seepage path diagrams, we can see that pumping groundwater causes a smaller drawdown outside the pit because of the deep flow path around the hole.

9. Conclusion

Based on the above calculation, it is found that with the increase of the depth of impervious curtain, pumping in the pit can cause a smaller drawdown outside. Compared with the 32m-impervious curtain, the drawdown outside under the condition of 37m- impervious curtain is reduced greatly, and the settlement of the soil outside the pit is greatly reduced. The bottom of the 47m-impervious curtain inserts into the 8-1 layer of mudstone, compared with the 37m-impervious curtain, the drawdown outside under this condition decreases slightly.

The influence of impervious curtain on seepage field cannot be neglected when pumping wells. When the impervious curtain is inserted deeply in the confined aquifer, the effect of pumping in the pit is obviously better than that outside the pit. For the pumping in the pit, the bottom depth of the filter shall be less than the depth of the bottom of the curtain, Otherwise, a large amount of groundwater comes from horizontal runoff, which increases the recharge of the pit from outside, and has a great impact on the outside of the pit, and loses the significance of the decompression pumping groundwater in the pit.

Therefore, in the general project, a reasonable filter position is required, at the same time make full use of the waterproof effect of the impervious curtain, in order to reduce land subsidence because of pumping groundwater in foundation pit.

Based on the above comparison and comprehensive analysis, it is recommended that the depth of the pensile curtain is set to 37m.

References

[1] Feng xiaola, Xie Wujun, Lu Zhiqiang, et al. Influence of suspended waterproof curtain on dewatering of foundation pit J]. soil foundation, 2006,20 (4): 33-36.J. van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2000) 51-59.

[2] Shen Yuanyuan, Jiang Yunzhong, Lei Xiaohui, et al. Study of artificial boundary treatment method in groundwater numerical simulation [J]. hydrogeology and engineering geology, 2008, (6):

12-15

[3] Song Yutian, Wei Maoxue, Qi Yong. Analysis of the depth of impervious curtain in deep excavation [J]. Shandong water conservancy, 2003, (8): 41-42.

[4] Chen Xinguo. Quantitative study on the influence of suspended water curtain on dewatering of foundation pit. Master's degree thesis (D). Wuhan: China University of Geosciences (Wuhan)

[5] Tang Guangming, Wang Jianping, et al. Numerical analysis of water stopping effect of suspended water curtain.[J]. construction technology development, 2011.7.38 (7)

[6] Jin Xiaowen, Ceng Bin, Liu Jianguo, et al. Discussion on key issues of numerical simulation in groundwater environmental impact assessment.[J]. hydropower energy science, 2014.5.32 (5):23-28.