Analysis of recharge test in floodplain area near Yangtze River in Nanjing

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Abstract. The suspended water curtain with groundwater recharge method are applied in thick sand aquifers to control the water level inside and outside the pit to avoid the negative impact due to its low cost and reliability. Recharge tests are carried out in floodplain area near Yangtze River for the construction of Heyan Road crossing River Passage. The result of test shows that the recharge can effectively rise the water level and the proper recharge pressure is 0.02 Mpa.

1. Introduction

Dewatering during the excavation of foundation pit may cause subsidence of surrounding soils. In severe cases, it leads to the oblique surrounding buildings or the cracking of underground pipelines, causing many engineering accidents and subsequent impacts, and brings great hidden dangers to people's property and safety.

The waterproof curtain is often used in the construction project to block the seepage path of the groundwater, to reduce the impact of the foundation pit on the surrounding ground and to protect the stability of the side wall of the pit. However, the thickness of the aquifer in the floodplain area near Yangtze River is huge. In this case, the cost of waterproof curtain that can completely cut off the aquifer is extremely high. In addition, the quality of the waterproof curtain (especially under the condition of deep sand layer) is difficult to guarantee, for example, the poor connection of the diaphragm wall joints and the inclination control problems make the water-proof effects of diaphragm wall difficult to satisfy engineering needs. Therefore, many projects need to use the suspended water curtain + groundwater recharge method to control the water level inside and outside the pit to avoid the negative impact of foundation pit on the surrounding buildings and soil during dewatering.

The surrounding environment of the Heyan Road Crossing River Passage Project requires high environmental protection. The retaining structure does not cut off the confined aquifer. When the foundation pit is excavated and dewatered, the groundwater level outside the pit changes greatly, so groundwater recharge is needed to reduce the subsidence of the soil outside the pit. In order to investigate the relationship between groundwater rise and ground rebound, a recharge test was conducted.

2. Project overview and geological conditions

The Heyan Road crossing River Passage is located between the Yangtze River Bridge and The Second Yangtze River Bridge, precisely 7.4km from the Yangtze River Bridge and 2.7km from the Second Yangtze River Bridge on the lower reaches. The starting point of the Heyan Road crossing River Passage (South Section) is at the intersection of Heyan Road and Yanheng Road. The end point is located at Puyi Baguazhou Interchange. The tunnel is adopted across the Yangtze River (the main river). The main line
The project is about 5.725km long. The tunnel section is 4215m, the subgrade section is 84m, and the elevated section is 1426m.

The climate of the project area is humid, rainfall is abundant, and the rainy season is long. The surface water bodies of the Yangtze River and other groundwaters have good hydraulic connections, and they have a replenishing effect on groundwater during the flood season, which plays an important role in regional groundwater recharge. According to the lithology, burial conditions, groundwater occurrence conditions and hydraulic characteristics of the aquifer, it can be divided into loose rock phreatic water, loose rock pore micro-confined water and bedrock fissure water.

Pore phreatic water of Quaternary loose rocks mainly occurs in shallow filling layer and upper soil layer of Yangtze River floodplain area. Aquifers in floodplain area near Yangtze River are mainly (1) layer, (2) 1 layer of cohesive soil and (2) 2 silty soil with thickness ranging from 5 to 20 m. Its permeability and water-content are poor and its water quantity is limited. The pore micro-confined water of loose rocks mainly occurs in the sandy soil of Baguazhou. Its sediments are of binary or multivariate structure, fine in upper part and coarse in lower part. The muddy soil and intermittent soil cover the floodplain area and are directly connected with the river water in the Yangtze River channel area. The local confined aquifer can be divided into two parts: the upper part is (2) 3 to (2) 6 layers of silt and fine sand, and the lower part is (4) layers of medium-coarse sand, gravel and round gravel. Fracture water in clastic bedrock mainly occurs in underlying bedrock and this aquifer is buried deeply and has little influence on engineering.

![Diagram of geologic section](image)

Figure 1. Diagram of geologic section

| Layer No. | a₀1−0.2 (MPa⁻¹) | e | φ (°) | c (kPa) | K(cm/s) |
|-----------|------------------|---|------|--------|--------|
| (2)-3     | 0.28             | 0.876 | 24.16 | 8.48   |
| (2)-4     | 0.15             | 0.705 | 30.89 | 4.05   |
| (2)-5     | 0.13             | 0.674 | 31.10 | 3.65   |
| (2)-6     | 0.12             | 0.673 | 31.21 | 5.04   |
| (2)-6-1   | 0.44             | 0.899 | 9.30  | 20.07  |
| (4)-1     | /                | 0.614 | 33.57 | 4.33   |

3. Groundwater recharge test
Recharge tests are carried out respectively for (2) 5 and (2) 6 layers to find out the proper target recharge aquifer, and to analyse the recharge parameters. The test site is only 350 meters from the Yangtze River.
The structural parameters of the test well are listed in Table 2, the layout of the test well is shown in Figure 2, and the structural profile of the pumping test well is shown in Figure 3.

Table 2. Structural parameters of the test well

| Layer No. | Well No.          | Depth of well (m) | Bore diameter (mm) | Well diameter (mm) | Length of filter (m) | Depth of filter (m) |
|-----------|-------------------|-------------------|--------------------|--------------------|----------------------|--------------------|
| (2)-5     | K2-5-1; G2-5-1~G2-5-3 | 25                | 650                | 273                | 10                   | 14-24              |
| (2)-6     | K2-6-1; G2-6-1~G2-6-3 | 35                | 650                | 273                | 10                   | 24-34              |
| (4)-1     | K4-1~K4-2         | 47                | 650                | 273                | 5                    | 41-46              |

Figure 2 Diagram of recharge test well location (K—for recharge well, G—for observation well)
4. Result of recharge test

4.1 Recharge test for (2)-5 layer
Pump with rated water output of 150 m³/h is put into pumping well G2-5-3. After water level is stable, adjacent recharge well K2-5-1 begins to recharge and the pressure of recharge increases gradually. The change of water level is shown in Fig.4. The result of test is shown in Tab.4.

The result of test shows that the recharge can effectively rise the water level and the proper recharge pressure is 0.02 Mpa.
Table 3. Comparison table before and after recharge

| Well No. | Distance to pumping well (m) | Distance to recharging well (m) | Drawdown after pumping (m) | Lifting after recharging (m) | Ratio lifting/drawdown |
|----------|------------------------------|---------------------------------|--------------------------|----------------------------|------------------------|
| G2-5-3   | /                            | 6                               | Pumping rate 143t/h      |                            |                        |
| K2-5-1   | 6                            | /                               | Recharging rate 26t/h     |                            |                        |
| G4-1     | 12                           | 6                               | 1.3                      | 0.37                       | 28.46%                 |
| G2-5-1   | 18                           | 12                              | 1.26                     | 0.4                        | 31.75%                 |
| G2-5-2   | 30                           | 24                              | 0.82                     | 0.21                       | 25.61%                 |
| G2-6-3   | 17                           | 13                              | 0.94                     | 0.21                       | 22.34%                 |
| K2-6-1   | 13                           | 12                              | 1.05                     | 0.22                       | 20.95%                 |
| G4-2     | 17                           | 13                              | 0.9                      | 0.18                       | 20.00%                 |
| G2-6-1   | 32                           | 26                              | 0.62                     | 0.14                       | 22.58%                 |
| G2-6-2   | 12                           | 13                              | 1.53                     | 0.27                       | 17.65%                 |

The stable recharge rate is 26 t/h, which is equivalent to 1/6 of the pumping rate. The maximum water level rise of the same structure observation well is 0.4m, which is equivalent to 31.75% of the water level recovery.

4.2 Recharge test for (2)-6 layer

Pump with rated water output of 150 m$^3$/h is put into pumping well G2-6-2. After water level is stable, adjacent recharge well K2-6-1 begins to recharge. The result of test is shown in Tab. 4.

Table 4. Comparison table before and after recharge

| Well No. | Distance to pumping well (m) | Distance to recharging well (m) | Drawdown after pumping (m) | Lifting after recharging (m) | Ratio lifting/drawdown |
|----------|------------------------------|---------------------------------|--------------------------|----------------------------|------------------------|
| G2-6-2   | /                            | 6                               | Pumping rate 193t/h      |                            |                        |
| K2-6-1   | 6                            | /                               | Recharging rate 29t/h     |                            |                        |
| K4-2     | 12                           | 6                               | 2.07                     | 0.42                       | 20.29%                 |
| G2-6-3   | 18                           | 9                               | 1.62                     | 0.29                       | 17.90%                 |
| G2-6-1   | 30                           | 25                              | 0.9                      | 0.12                       | 13.33%                 |
| G2-5-3   | 12                           | 13                              | 1.92                     | 0.2                        | 10.51%                 |
| K2-5-1   | 13                           | 12                              | 1.65                     | 0.19                       | 11.51%                 |
| K4-1     | 20                           | 13                              | 1.03                     | 0.17                       | 16.5%                  |
| G2-5-1   | 25                           | 17                              | 1.28                     | 0.13                       | 10.15%                 |
| G2-5-2   | 34                           | 27                              | 0.95                     | 0.12                       | 12.63%                 |

The stable recharge rate is 29 t/h, which is equivalent to 1/7 of the pumping rate. The maximum water level rise of the same structure observation well is 0.42m, which is equivalent to 20.29% of the water level recovery.
5. Conclusions
In the floodplain area near Yangtze River in Nanjing, the sand layer is thick and the permeability coefficient is very high. The output water of a single well exceeds 100 m3/h. Therefore, a large amount of recharge is needed to maintain the water level at an appropriate height.

The result of test shows that the recharge can effectively rise the water level and the proper recharge pressure is 0.02 Mpa. According to the test results of integrated pumping and recharge, the water level of the (2)-6 layer is greatly affected by the recharge of (2)-5 layer. Under the condition of atmospheric pressure recharge, the rise ratio of water level in 5 layers is 31.75%, and that in 6 layers is about 20%. When atmospheric pressure recharge (2) 6 layers, (2) water level rise ratio of 5 layers is 10%. According to the effect of water level rise, the target layer of recharge is 2-5 layers.

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