Subsidence inhibiting effect of recharge in floodplain area near Yangtze River

Song Xiangdong1*, Qu Chengsong1
1 Shanghai Changkai Geotechnical Engineering Co., Ltd., 200093, China
*Corresponding author’s e-mail: songxiangdongsd@163.com

Abstract. The excavation of pit and the dewatering during the excavation leads to evident subsidence of surrounding buildings and structures. Groundwater recharge during the construction of Heyan-road-crossing-river-passage shows a clear subsidence inhibiting effect even though the work site is only 500 meters away from Yangtze River. Totally 217 recharge wells were arranged around the pit and the average recharge rate was about 2m³ per hour. The subsidence inhibiting effect of recharge can decrease the environment risk caused by pit construction.

1. Introduction
The southern part of the Heyan-road-crossing-river-passage is 5.725 km long with 4.215 km tunnel section under Yangtze River and 1.426 km elevated section located at Baguazhou, an ait in Yangtze River. 239m of the elevated section was constructed with open-cut and buried method. The work site is only 450 meters from Yangtze River, so its static groundwater-level is affected by the tides of the Yangtze River and the fluctuation range is 15~25cm.

Figure 1 Location of work site

The depth of pit in this site varies from 0.39m to 25.7m as shown in Tab.1. In order to excavate the pit without the affect of groundwater, dewatering wells are arranged in the pit where the excavating depth exceeds 3 meters.
Table 1. Details of foundation pit

| Mileage (m) | Length (m) | Depth of pit (m) | Width of pit (m) | Foundation pit form (Depth: m) |
|-------------|------------|-----------------|-----------------|-------------------------------|
| ZK4+691~ZK4+712 | 21 | 25.7 | 46 | 1000mm continuous concrete wall 48 |
| ZK4+715.5~ZK4+760 | 48 | 19.894~22.136 | 35.14~36.147 | 800mm continuous concrete wall 28 |
| ZK4+804~ZK4+834 | 30 | 12.814~14.099 | 33.907~34.43 | 31 |
| ZK4+834~ZK4+891 | 57 | 10.443~12.814 | 32.911~33.907 | 6000mm continuous concrete wall 25/23.5 |
| ZK4+891~ZK4+951 | 60 | 7.961~10.443 | 33.907~52.35 | 21 |
| ZK4+951~ZK4+981 | 30 | 6.67~7.961 | 47.942~54.463 | 16 |
| ZK4+981~ZK5+0411 | 30 | 5.479~6.67 | 47.068~47.942 | φ650 engineering piles 14 |
| ZK5+011~ZK5+041 | 30 | 3.77~5.479 | 45.838~47.068 | 11 |
| ZK5+041~ZK5+071 | 30 | 2.975~3.77 | 46.694~45.971 | 10 |
| ZK5+071~ZK5+131 | 60 | 0.386~2.975 | 44.523~45.838 | steel sheet piles 6/9 |

In this site, confined aquifers are thick, consisted of silt, fine sand, medium-coarse sand, gravel and round gravel, as shown in Fig.2. The permeability of aquifers is about 10~90 m/d, and the pumping rate of well is about 100~300 m³/h.

2. Prediction of subsidence caused by dewatering

In order to predict the drawdown of groundwater, the software Visual Modflow is applied by building a three-dimensional model. When the water-level in the pit reaches the maximum designed depth, the contour map of the water-level is predicted as shown in Fig.3.(a).

The influence range of dewatering can reach 1000m. The water level drawdown outside the pit is about 5m in the range of 70m from the pit, the water level drawdown outside the 300m is about 3m, and the water level drawdown outside 500m is less than 2m. It can be concluded that the influence range of the ground subsidence should be at least 500m, and the ground subsidence should occur within 70m from the deepest part of the pit.
According to the excavation conditions, a subsidence prediction model is established. During the excavation process, the actual dewatering period is short, which usually does not exceed 90 days. At the end of this period, the contour map of the cumulative subsidence of the ground outside the pit caused by dewatering is shown in Fig. 3(b). The maximum subsidence is 160mm, and the maximum subsidence of nearest building is about 75mm.

Table 2. Prediction of water drawdown and subsidence

| Distance between building and foundation pit (m) | Water level drawdown(m) | Subsidence(mm) |
|------------------------------------------------|------------------------|----------------|
| <70                                            | >3                     | >75            |
| 70~300                                         | 3~5                    | 50~75          |
| 300~500                                        | 1.5~3                  | 20~50          |
| >500                                           | <1.5                   | <20            |

3. Design and implementation of recharge wells

The confining structure does not cut off the confined aquifer, so there is a hydraulic connection between the inside and outside of the foundation pit. Therefore, when dewatering is carried out in the pit, the influence on the surrounding area is difficult to avoid. Therefore, it is necessary to lay back the recharge wells along the residential buildings and the river embankment to reduce the decrease of the water level outside the pit and the ground subsidence of the pit. When the water drawdown is too large, the recharge wells are open to apply the recharge measures, to raise the groundwater level artificially, maintaining the balance of water and soil outside the pit, and to slow down the settlement deformation.

The recharge wells are arranged within the site area near the protected building. The depth of the recharge wells is 25 meters and the length of the filter part of the well is 15 meters. The diameter of the recharge wells is 0.273 meter. Totally 217 recharge wells were arranged around the pit, as shown in Fig. 4.
4. Result and conclusion
The foundation pit has a large amount of water because its lower aquifer is very thick, and the permeability is extremely high. Pumping rate of deep well in the pit reaches 240m³/h. Due to the quality of continuous concrete wall does not meet the design requirement, dewatering during the excavation of pit leads to larger water drawdown than expected. The maximal water drawdown outside the pit is 10 meters while the maximal water drawdown inside the pit is 24 meters. The subsidence rate of the residential houses is around 2mm per day.

In this case, the recharge wells with atmosphere pressure are switched on. The recharge rate of each well is about 20 m³ per day. The subsidence rate of the residential houses decreases to 1mm per day. Then the pressurization devices are carried out, and the recharge pressure increases to 0.06 MPa. The recharge rate increases to 48 m³/day, making the water level maintain at -4.03 m and the subsidence rate of the residential houses decreases to 0.3 mm/day.

The result shows that the recharge can effectively rise the water level and has a clear subsidence inhibiting effect. Even though in the thick aquifer with high permeability and abundant groundwater supply, the recharge still can maintain the water level outside the pit and decrease the subsidence during the excavation.

References
[1] Miyake N, Kohsaka N, Ishikawa A. Multi-aquifer pumping test to determine cut off wall length for groundwater flow control during site excavation in Tokyo, Japan[J]. Hydrogeology Journal, 2008, 16(5):995-1001.
[2] Pujades E, Lopez A, Carrera J, et al. Barrier effect of underground structures on aquifers[J]. Engineering Geology, 2012, 145-146:41-49.
[3] Wang JX, Feng B, Guo TP, et al. Using partial penetrating wells and curtains to lower the water level of confined aquifer of gravel[J]. Engineering Geology, 2013, 161:16-25.
[4] Wu YX, Shen SL, Xu YS, et al. Characteristics of ground water seepage with cut-off walling ravel aquifer. Field I: observations [J]. Canadian Geotechnical Journal, 2015, 52(10):1526-1538.
[5] Wu YX, Shen SL, Xu YS, et al. Characteristics of ground water seepage with cut-off walling ravel aquifer. I: Field II: Numerical analysis [J]. Canadian Geotechnical Journal, 2015, 52(10):1539-1549.