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Full Length Article

Optimization of dewatering schemes for a deep foundation pit near the Yangtze River, China

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ABSTRACT

A deep foundation pit constructed for an underground transportation hub was excavated near the Yangtze River. Among the strata, there are two confined aquifers, between which lies an aquiclude that is partially missing. To guarantee the safety of pit excavation, the piezometric head of the upper confined aquifer, where the pit bottom is located, should be 1 m below the pit bottom, while that of the lower confined aquifer should be dewatered down to a safe water level to avoid uplift problem. The Yangtze River levee is notably close to the pit, and its deformation caused by dewatering should be controlled. A pumping test was performed to obtain the hydraulic conductivity of the upper confined aquifer. The average value of the hydraulic conductivity obtained from analytical calculation is 20.45 m/d, which is larger than the values from numerical simulation (horizontal hydraulic conductivity K_H = 16 m/d and vertical hydraulic conductivity K_V = 8 m/d). The difference between K_H and K_V indicates the anisotropy of the aquifer. Two dewatering schemes were designed for the construction and simulated by the numerical models for comparison purposes. The results show that though the first scheme could meet the dewatering requirements, the largest accumulated settlement and differential settlement would be 94.64 mm and 3.3‰, respectively, greatly exceeding the limited values. Meanwhile, the second scheme, in which the bottoms of the waterproof curtains in ramp B and the river side of ramp A are installed at a deeper elevation of −28 m above sea level, and 27 recharge wells are set along the levee, can control the deformation of the levee significantly.

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1. Introduction

In recent years, due to the rapid development of urbanization, underground spaces have been widely exploited and utilized. Construction of underground projects, such as the base of high-rise buildings, subway stations, and underground transportation corridors, always encounters the problems of foundation pit excavation (Fu et al., 2014; Ma et al., 2014; Xing et al., 2016). Construction of tunnels or foundation pits usually results in surface settlement (Fattah et al., 2011, 2013). However, a high groundwater level will increase the difficulty and reduce the safety of construction. Subsequently, dewatering is vital in pit excavation, especially for a large and deep foundation pit in confined aquifers with high piezometric head (Forth, 2004; Li and Pei, 2011; Ding et al., 2014; Pujades et al., 2014).

The lowering of the groundwater level outside the pit can lead to ground subsidence, affecting the stability of surrounding buildings. Thus drawdown of the groundwater outside the pit must be strictly controlled (Chen and Xiang, 2006; Ding et al., 2011). In sedimentary strata, the horizontal hydraulic conductivity (K_H) of the aquifer is usually greater than the vertical value (K_V) (Wang et al., 2013a; Wu et al., 2016). Combination of partially penetrating wells and curtains can change the groundwater flow from a horizontal direction to an approximately vertical direction and lengthen the flow path (Zhou et al., 2010; Wang et al., 2014, 2016). As a consequence, less pumping wells, slower pumping rates and less time are needed, and the drawdown of groundwater level outside the pit could be much smaller than that inside. Water recharge is another effective method to control ground subsidence by injecting water into aquifers to reduce or balance the drawdown of groundwater level (Yuan and Li, 2015; Wang et al., 2012).

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Numerical simulation has been demonstrated to be a useful approach to evaluate the effect of dewatering in a foundation pit, calculate the ground subsidence and adjust the hydraulic parameters of aquifers (Su et al., 1998; Shen et al., 2006; Luo et al., 2008; Kaneda and Yamazaki, 2009; Zhang et al., 2013). Some three-dimensional (3D) numerical simulation packages have been widely used by many researchers, such as Visual MODFLOW, in which the governing equation is solved by the finite difference solution (Painter et al., 2008; Wang et al., 2013b; Xu et al., 2016a).

In August 2014, the Second Youth Olympic Games was held in Nanjing, Jiangsu Province, China. To ease traffic pressure, a cross-river tunnel was constructed by shield method under the Yangtze River, to link the playing venues on both sides of the river. The construction site is located in the southwestern part of the city. As the southeast entrance of the tunnel, an underground transportation hub, which is the largest underground interchange at present in China, was constructed by open cut method. Thus excavation and dewatering design of the foundation pit was inevitable. To meet the dewatering requirement and reduce the deformation of the nearby buildings caused by dewatering, partially penetrating wells, in combination with waterproof curtains, were adopted. However, the aquiclude between two confined aquifers is partially missing, and some parts of the aquifers were not isolated by the curtains. The dewatering design should consider the different hydrogeological conditions of each area of the foundation pit. A 3D numerical simulation was adopted to evaluate the effect of the dewatering schemes. This paper aims to propose the optimal dewatering scheme according to the simulation results and provide reference to similar engineering projects.

2. Background

2.1. Deep foundation pit

The foundation pit is located in the southeastern bank of the Yangtze River, only 120 m away from the river (Fig. 1). The foundation pit consists of three ramps (A, B and C) and a main road connecting the cross-river tunnel. Ramps A and B connect the Yangzijiang Road on the ground and ramp C connects the Youth Olympic Center, which will be constructed in the future. The length and width of the foundation pit for the main road are 213 m and 110 m, respectively. The width of the ramp pits is approximately 12 m. Unlike normal rectangular-shaped excavation, the shape of this foundation pit is irregular and the depth is not uniform. The bottom elevation of the main road foundation pit reduces gradually from the southeast to the northwest, ranging from −11.88 m to −19.45 m, downward toward the tunnel, while those of the three ramp pits increase from the main road to the ground, ranging from −9.66 m to −5.76 m for ramp A, −11.46 m to −1.95 m for ramp B, and −9.92 m to −2.82 m for ramp C (Table 1). The elevation of the

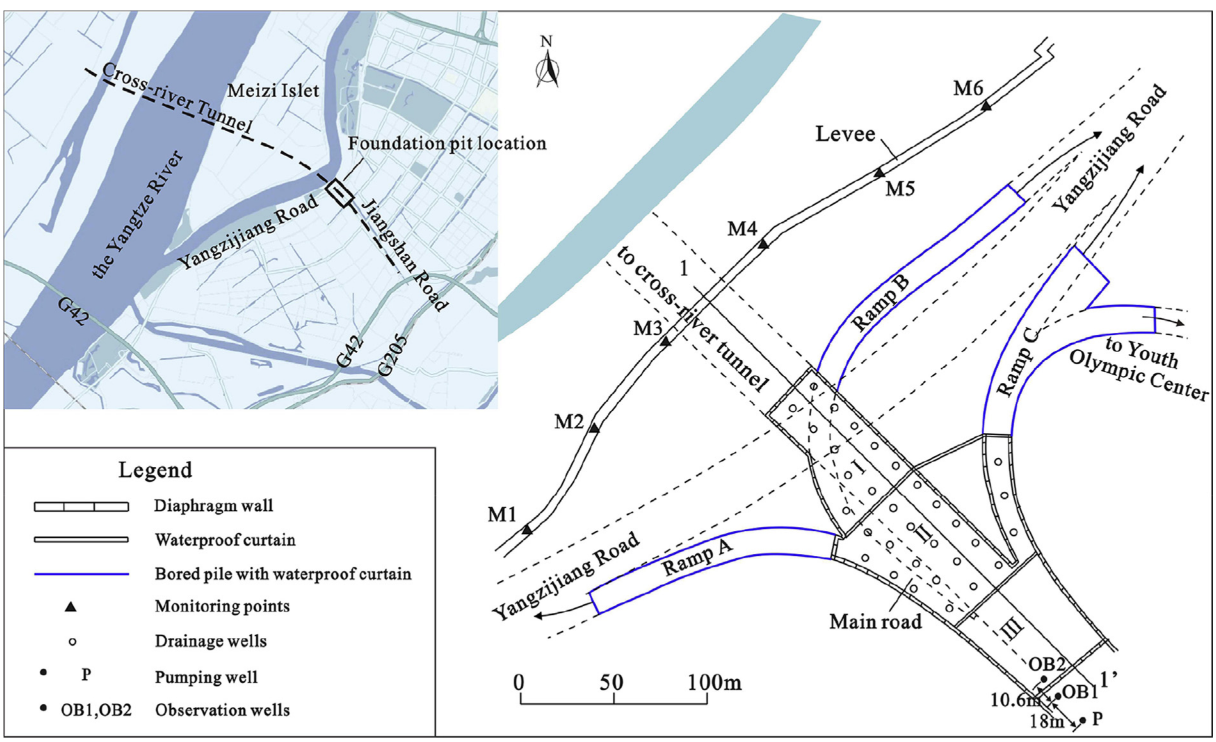

Fig. 1. Location and plane layout of the foundation pit.

Table 1
Parameters of the foundation pit and piezometric head requirements of two confined aquifers.

Foundation pit		Pit bottom elevation (m)	Support structure bottom elevation (m)	Piezometric head requirements (m)	
				Upper confined aquifer	Lower confined aquifer
Main road	Region I	−19.45 to −16.21	−45	−20.45 to −17.21	−4.77
	Region II	−16.21 to −13.26	−38	−17.21 to −14.26	0.95
	Region III	−13.26 to −11.88	−38	−14.26 to −12.88	
Ramps	A	−9.92 to −2.82	−19.4 to −7.65	−10.92 to −3.82	12.04
	B	−9.66 to −5.76	−17.4 to −13.5	−10.66 to −6.76	12.5
	C	−11.47 to −1.95	−18.9 to −7.9	−12.47 to −3.95	9.31

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