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Using partial penetrating wells and curtains to lower the water level of confined aquifer of gravel

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ABSTRACT

To address the difficulties of penetrating and dewatering of a deep and thick confined aquifer of gravel, a dewatering approach that considers the anisotropic hydraulic conductivity of aquifer, co-work of partial penetrating curtains, and partial penetrating pumping wells was developed. Using the deep foundation pit of the southern ventilation shaft of Metro Line 1 in Hangzhou, China, as an example, a numerical simulation model based on finite difference method was established to invert the parameters and determine the co-work of partial penetrating curtains and wells. The anisotropic characteristic of the aquifer indicated that the three-dimensional flow caused by partial penetrating wells produced bigger drawdown. By co-working with the partial penetrating wells, the partial penetrating curtains changed the horizontal flow to a vertical one, lengthened the flow path, and consumed more energy to produce bigger drawdown. Three simulation schemes with different lengths, depths of well screen, and pumping rates were performed. The results indicated that a short screen for the pumping well embedded by curtains resulted in the biggest drawdown with minimum pumping rate. Based on numerical simulations, four pumping wells with 4 m-long screens embedded by curtains were installed inside the excavation zone. The water level declined to the required drawdown, which indicated that the approach is feasible and can provide solutions to problems on similar projects.

1. Introduction

Dewatering is often necessary to lower water level and ensures safety during excavation of a deep foundation pit. However, lowering the water level within a deep and thick confined aquifer of gravel is difficult due to its large hydraulic conductivity. Pumping tests have indicated that reducing water level in the aquifers using only pumping wells is difficult (Wang, 2009). Because that a large pumping rate only produces a small drawdown in the aquifer. For a foundation pit that only permits installation of a limited number of pumping wells, obtaining a large drawdown using a large number of pumping wells is difficult. Curtain penetration into a deep and thick confined aquifer of gravel is difficult and expensive, and complete isolation cannot be accomplished through curtain installation. Curtains, such as diaphragm walls, are often designed to penetrate into partially the aquifer. When the required drawdown cannot be attained, underwater construction method, both time consuming and dangerous to workers, often has to be adopted.

During the excavation of water-rich formation with high permeability, groundwater is a very important factor controlling pit stability. Dewatering is a widely used approach to decrease the piezometric level around a foundation pit. However, it may cause land subsidence (His et al., 1994; Tang et al., 1999; Roy and Robinson, 2009). In the past, numerous successful dewatering cases of deep foundation pits have been performed in sand- and silt-confined aquifers (Luo et al., 2008; Wang et al., 2009). Dewatering system, together with hydraulic barrier, has been used to prevent depressurization of confined aquifers and triggering of settlements within soft-soil aquitards that cap confined aquifers. However, the formations in these studies were very impermeable compared to the rounded gravel formation of this study. Phreatic aquifers or the formation was mixed with sand, silt, and clay.

Pumping tests have been performed in gravel (Qu and Chen, 2010). However, the tests were designed to develop a new method of evaluating the hydraulic parameters of partial penetration wells. Multi-well pumping tests were conducted in the deep gravel formation of Taipei Basin to derive the hydraulic parameters and to investigate the drawdown characteristics at both the construction and remote sites. A method to remove the factors of tidal effect, wellbore storage, skin and leakage influencing the drawdown curve has been developed (Ni et al., 2011). Numerical simulations were performed in foundation pit dewatering in confined aquifer of sands or silts (Luo et al., 2008; Wang et al., 2009, 2012a, 2012b; Zhou et al, 2010), and several were performed in optimizing curtain depth to control subsidence (Wang et al., 2009; Zhou et al, 2010). However, the

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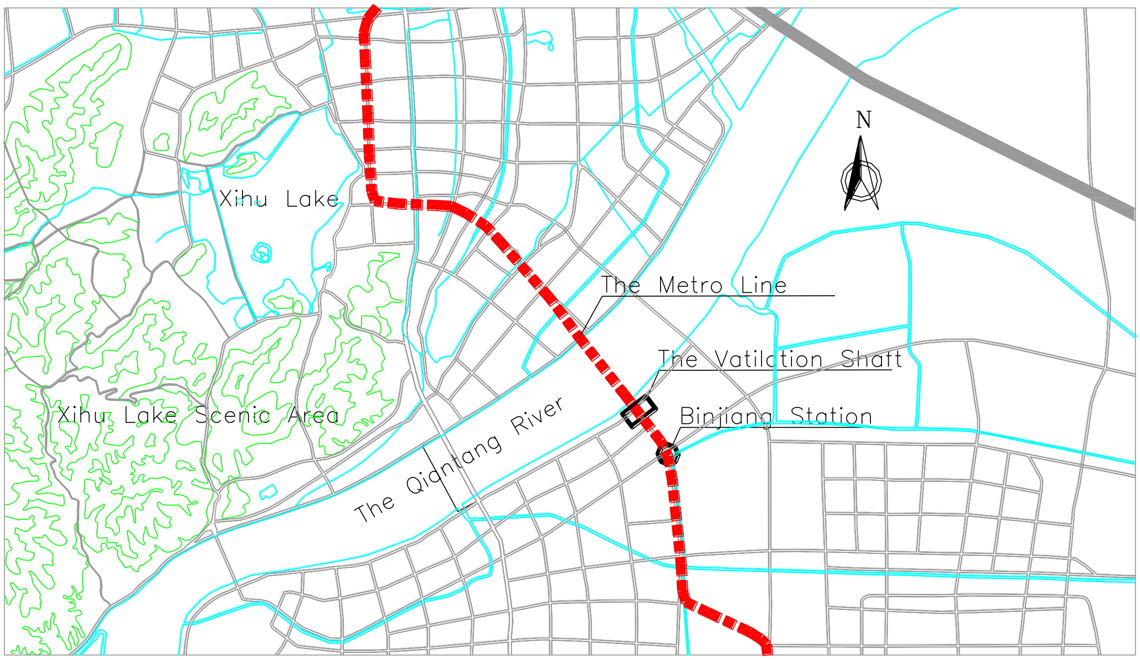

Fig. 1. Location of the ventilation shaft.

co-work of partial penetrating wells and curtains to lower water level in confined aquifer of gravels was not studied in the previous simulations.

In 2007, dewatering of a confined aquifer of gravel was attempted in the shaft wells of Qingchun Road tunnel across the Qiantang River in Hangzhou, China. Nine pumping wells were employed outside the diaphragm wall. The water level declined from −3.00 m to −7.00 m. Only 4 m drawdown was achieved. The construction of a diaphragm wall (47 m deep) in the south shaft well of the Qingchun Road tunnel was completed before the dewatering. However, the pumping wells

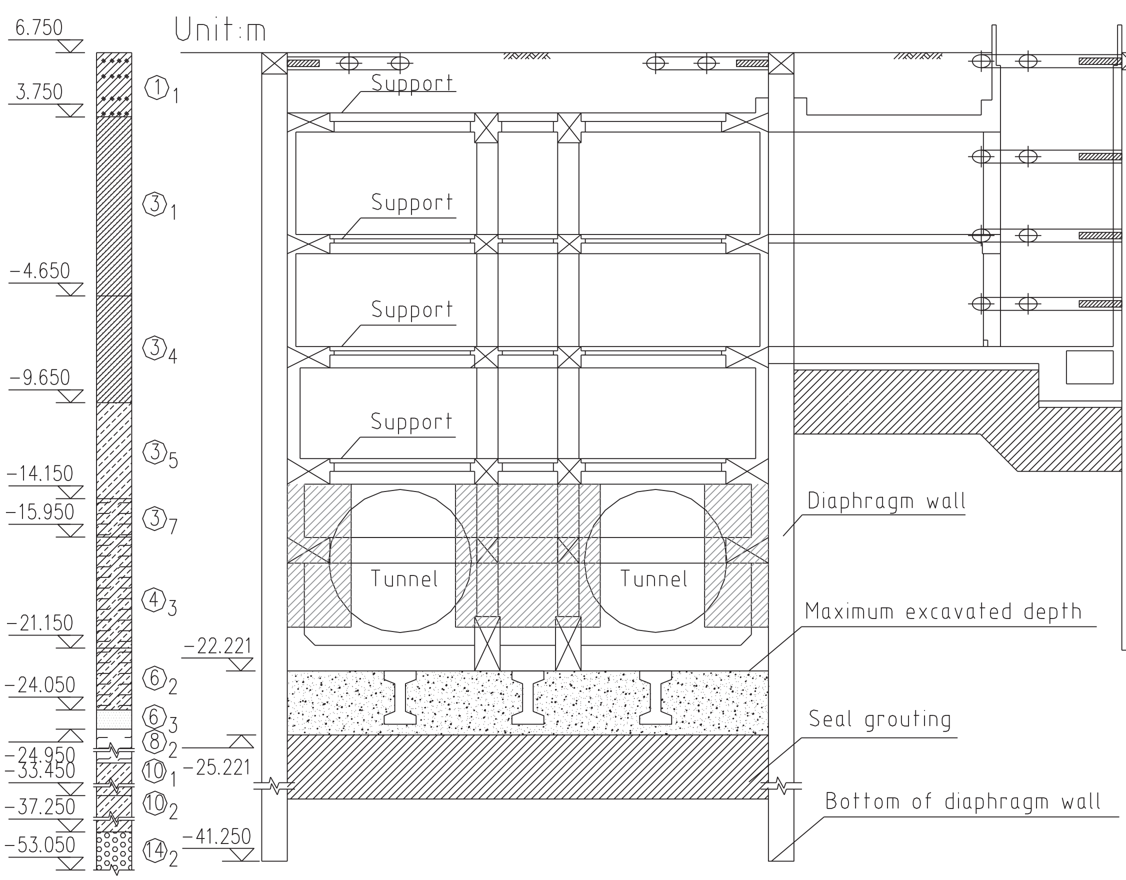

Fig. 2. Profile of the retaining structure.