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To cite this article: Song Xiangdong *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **310** 022040

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# Application of Groundwater Recharge for controlling the Subsidence of Metro section caused by dewatering

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**Abstract.** Even a slight subsidence of metro may lead to a severe threat to the safety of metro operation. Groundwater recharge is a valid manner to control the subsidence caused by dewatering. The recharge application in the foundation pit near Metro Line 8 in Shanghai shows that the recharge can effectively rise the water level and even rebound the ground, which ensures the safety of deep foundation pit excavation. The result can help the design of recharge well for projects with similar hydrogeological conditions.

## 1. Introduction

Along with the rapid development of the economy, the intensity and complexity of urban architecture are increasing day by day. The urban space is gradually expanding deeper and higher, and various large, deep and ultra-deep foundation pits are constructed. Meanwhile, the requirements for environmental deformation around the urban geotechnical construction site are getting higher and higher. Among the many influencing factors of geotechnical construction on the surrounding environment, the problem of ground subsidence occupies a very important position. Soils deposited for a long time, in which soil particles, gas, and water have formed a stable state, and any change in the phase of the soil may directly or indirectly cause deformation of the soil. The problem of soil subsidence caused by changes in groundwater level has become increasingly prominent. When the groundwater level is dewatered too deep, the ground is deformed, which threatens the safety and normal use of buildings, structures and pipelines. Therefore, in the process of deep foundation pits construction, under the condition of satisfying the deepening of the water level of the foundation pit, the drawdown of groundwater level around the foundation pit should be minimized, and the influence on the surrounding environment can therefore be effectively controlled.

Operating metro tunnels require extremely high deformation control. According to *Interim Provisions of Subway Protection for Construction along the Shanghai Metro Line (1994)*, the absolute subsidence and horizontal displacement of the subway structure facilities should be inferior to 20 mm (including the final displacement of various loading and unloading). In the actual project, the subsidence limit is much stricter. For example, during the construction of Metro Line 8 at People Square Station, the longitudinal subsidence and elevation control of the tunnel structure of Metro Line 2 are  $\pm 5\text{mm}$ , and the longitudinal horizontal displacement control is  $\pm 5\text{mm}$ . Therefore, if the groundwater recharge could curb the subsidence in effect, it will be crucial for the construction of deep foundation pit near metro.



## 2. Project overview and geological conditions

A 11686.7m<sup>2</sup> foundation pit with the depth of 17.6m is located near the Metro Line 8 in Shanghai. The nearest distance from the pit to the metro is only 9.3m and the length of metro section near the pit is 120m, as shown in Fig.1.

According to the survey results of this project, most of the site was cut by the ancient river watercourse, ⑥ layer was missing, and ⑦<sub>1</sub> layer was cut in varying degrees, corresponding to thicker ⑤<sub>3</sub> layer of soil.

The type of groundwater in Shanghai is mainly loose rock pore water. Pore water can be divided into phreatic aquifer, micro-confined aquifer and confined aquifer according to the formation age, genesis and water features. In this site, groundwater types involved are phreatic aquifer in ③ and ④ layer and micro-confined water in the ⑤<sub>2</sub> layer, and I and II confined water in the ⑦ layer and ⑨ layer.



Figure 1. Location of pit and metro

Table 1. Physical and mechanical properties of soil

Layer No.	$a_{0.1-0.2}$ (MPa <sup>-1</sup> )	$\gamma$ (KN/m <sup>3</sup> )	$\varphi$ (°)	$c$ (kPa)	K(cm/s)
②	0.37	18.6	19	20	3.00E-06
③	0.7	17.6	18.5	12	4.00E-06
④	1.13	16.9	12	11	3.00E-07
⑤ <sub>2</sub>	0.47	18	20	15	1.89e-04
⑦ <sub>2</sub>	0.13	18.7	26.5	8	3.00E-03
⑨	0.12	18.6	39	2	5.00E-02

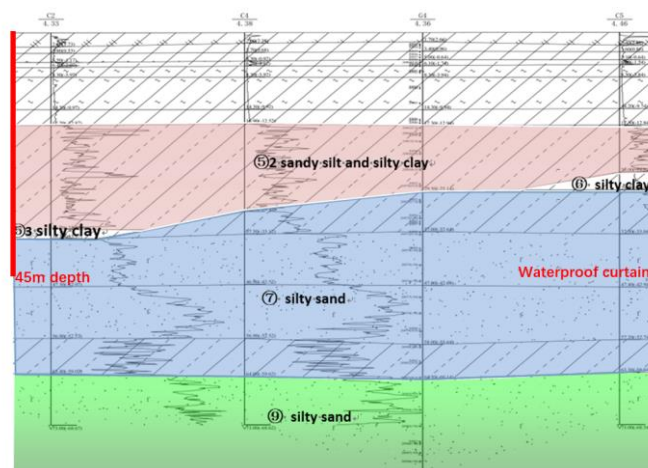


Figure.2 Diagram of geologic section

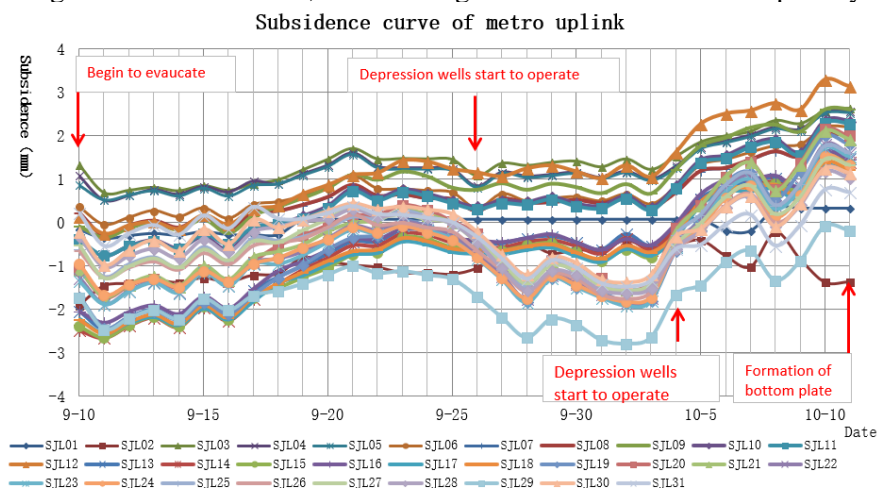
The waterproof curtain is made of 1000mm thick underground continuous wall with a depth of 45m. Although the waterproof curtain cuts off ⑤<sub>2</sub> layer inside and outside of the pit, water in the ⑤<sub>2</sub> layer, ⑦ layer and ⑨ layer are connected to each other, and there is a obvious hydraulic connection. Therefore, when the ⑤<sub>2</sub> layer dewatering is performed in the pit, the influence on the periphery is difficult to avoid, especially the metro side has higher control requirements for deformation.

### 3. Water recharge result

The ⑤<sub>2</sub> layer water emergency recharge well are arranged outside the pit. When the dewatering of the foundation pit causes the water level outside the pit to drop drastically, the recharge well is operated to recharge the groundwater level, artificially raise the water level outside the pit, and slow down the deformation. The distance between the adjacent recharge well near the metro is 15m, and a total of 7 recharge wells are arranged. The depth of recharge well is 30m, and the filter tube is set from 20m to 29m.

Since the excavation of the third layer on September 27, 2016, the deep well of decompression began pumping, the water level of the confined water in the foundation pit was controlled to the designed water level.

From the subsidence curve of the up-and-down line of the section tunnel of Metro Line 8 adjacent to the foundation pit, it is obvious that with the excavation of the foundation pit, ⑤<sub>2</sub> layer water level decreased gradually, and the whole tunnel was affected by the change of water level. From October 4th, the atmospheric pressure automatic recharge of the emergency recharge well outside the pit near the subway side started in time, and the water level outside the pit raised to 3m high than the initial water level. After the start of recharge, ⑤<sub>2</sub> layer water level raised evidently, and the subway section tunnel stopped subsiding and even uplifted. Later, the water level was controlled to 1m high than the initial water level by using an automatic recharge water level control device until the bottom plate of the foundation pit was completed. During the two-month atmospheric pressure recharge period, the cumulative recharge amount is 350 tons, with recharge rate of about 5 to 6 tons per day.



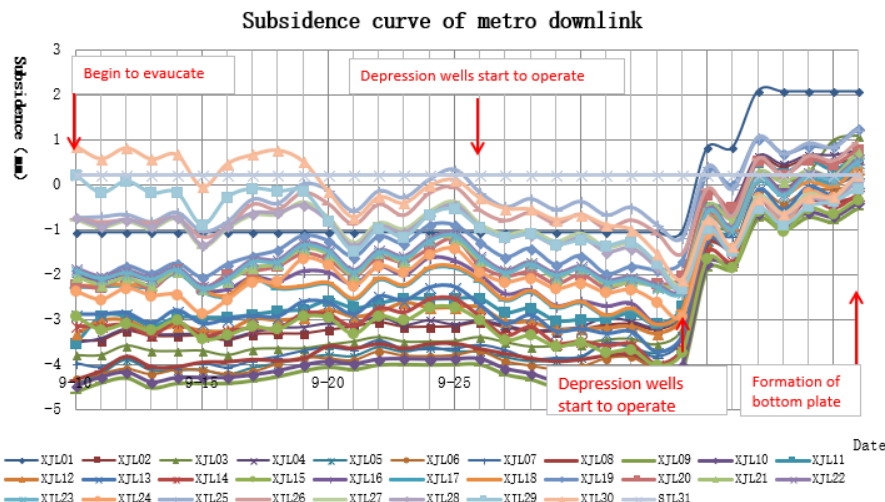


Figure.4 Subsidence curve of metro downlink

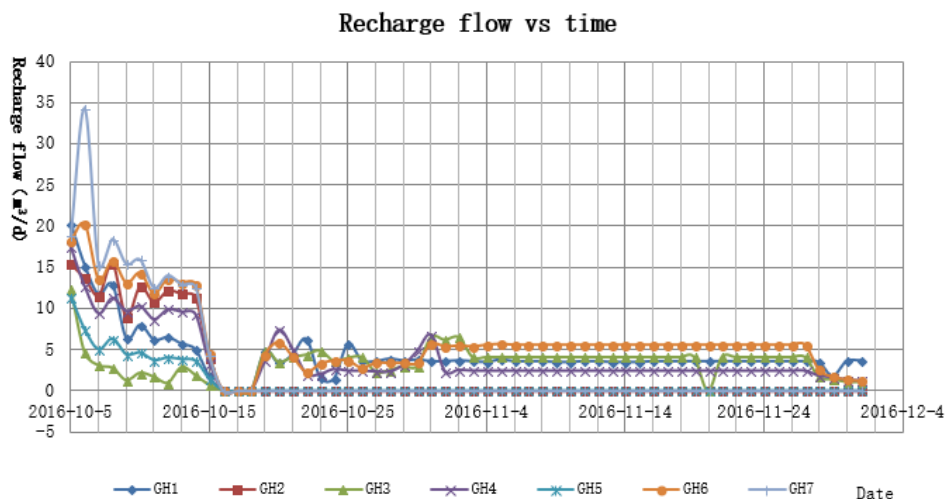


Figure.5 Recharge flow of each recharge well

#### 4. Conclusions and prospects

A group of seven recharge wells were arranged outside a 16m deep pit nearby the Metro Line 8 in Shanghai. The waterproof curtain with a depth of 45m can not cut off hydraulic connection inside and outside of the pit, as water in the ⑤<sub>2</sub> layer, ⑦ layer and ⑨ layer are connected to each other.

The recharge well is of 30m long and the aimed recharge aquifer is ⑤<sub>2</sub> layer of sandy silt and silty clay.

The application of recharge can effectively raise the water level outside the deep foundation pit and slow down the subsidence caused by the dewatering. The use of automatic-recharge-water-level-control-device can control the water level of recharge well without the help of workers, which economizes the labour costs and responses quickly to the variation of water level caused by emergency.

This case shows a perfect example for the use of recharge in controlling the subsidence in environment-sensitive structure such as metros and shallow-foundation buildings. It gains experience in the design of recharge well in similar project in Shanghai.

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