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Study on the actual case of deep excavation in sands and pebble with plenty water

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Abstract. Based on the deep excavation of Fengxihe Station of Chengdu Metro Line 17, the groundwater treatment plan for the deep sandy pebble stratum in Wenjiang district of Chengdu, the hole forming process of the retaining pile and the design of the retaining structure and the on-site monitoring data were analyzed and studied. Through systematic research on key technologies, the design and construction optimization schemes are proposed, and the relevant information of on-site information construction is enriched, which provides reference and reference for the design and construction of station excavations in similar strata.

1 Introduction

A prominent problem in the construction of the subway is the design and construction of the deep excavation. How to rationally design the excavation support and construction plan, which is economical, reasonable, safe and reliable, has become one of the important research topics in the geotechnical engineering field. The subway excavation deep excavation project is the most risky stage in the subway civil construction process. Especially when there are important buildings and pipelines around the excavation, the large ground displacement and settlement will affect its normal use and excavation safety[1]. The row pile and internal support structure are a kind of support form widely used in deep excavations in China, and have been widely used in the deep excavation engineering of metro stations in Chengdu area.

The water-rich sandy pebble stratum in Chengdu has the characteristics of loose structure, high content of pebbles and boulders, no cementation, large permeability coefficient, poor self-stability, high strength of single stone, and skeleton function of pebble in the stratum. At present, there is still little domestic engineering experience for the excavation and retaining structure design of excavations under such stratum conditions[2]. Therefore, how to ensure the rational design, safety and reliability of the excavation of Chengdu sandy pebble stratum station has become an urgent problem for engineers.

2 Project overview

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Fengxihe Station is the fourth station from the Yiyuan Park Station on the first phase of Line 17, and is interchanged with Fengxihe Station on the 4th line. The station is located on the west side of the intersection of Fengxi Avenue and Nanxuan Avenue, and lay along the east-west direction of Fengxi Avenue.

The excavation of Fengxihe Station of Chengdu Metro has the characteristics of the general pit of the subway station, namely "deep" and "big". The station is a three-story, two-column, three-span island station with a total length of 216.2m and a standard section width of 22.7. m, both ends of the section are shield sections, the depth of the excavation is about 28.7~30.0m, and the bottom plate of the station is located in the dense pebble soil layer. The station groundwater is mainly the pore type diving in the Quaternary sandy pebble stratum.

Intensive buildings around the station. The main surrounding environment is: the 9th detachment of the armed police on the northeast side of the station (brick 5/7, shallow foundation) is about 10m away from the main body of the station; the Rongxing Garden Community on the north side of the station (brick 3/4, shallow foundation), distance The main body of the station is 5.6m; the south side of the station is Xiangyang Mingyuan (brick 2~6, shallow foundation). As shown in figure 1.

Fig. 1. Location map of Fengxihe Station.

3 Engineering geological conditions

Although Chengdu has successfully built Metro Line 1 Phase 1, Line 2 Phase 1, Line 2 West Extension Line and Line 3 Phase 1, Line 4 Phase 1, Line 4 Phase 2 and Line 7, but according to the preliminary engineering geological and hydrogeological data, the first phase of the Metro Line 17 project in the Wenjiang section is located at the maximum pebble content of more than 75%, the size of the boulders is 20～70cm, and the uniaxial compressive strength of the pebble It may exceed 132 MPa in large particle size, high strength, water-rich sandy pebble stratum. Compared with the central urban area, this sand-pebble stratum has the characteristics of large diameter of boulders, high content of boulders, and poor density of pebble in some sections. As shown in figure 2 and figure 3.

Fig. 2. Great quantity drifting stone.

Fig. 3. Drifting stone 40cm or more.

The main geotechnical engineering features and hydrological characteristics of this project are described in detail in the following table 1:

Table 1. Engineering characteristics and hydrological characteristics of rock and soil layers statistical table.

Layer number	Name	Engineering characteristics	Hydrological characteristics	Uniformity
<1-2>	Artificially filled soil	Mottled, slightly wet, loose, layer thickness of about 1.0 ~ 3.4m.	A small amount of water, water-rich poor, micro-permeable ability.	More miscellaneous ingredients and usually contain pebble, sand and containing a partial construction waste, concrete, poor uniformity
<3-8-1>	Slightly dense pebble soil	Gray, grayish yellow, slightly dense, moist-saturated, filled with medium fine sand. The layer thickness is 2.0 to 9.7 m.	Generally the amount of water, good water-rich, high water permeability.	Pebble content of about 60% to 65%, for medium and fine sand filling, poor sorting
<3-8-2>	Medium dense pebble soil	Gray, grayish yellow, medium dense, saturated, filled with medium fine sand, layer thickness 4.7 ~ 10.8m.	Generally the amount of water, good water-rich, high water permeability.	Pebble content of about 65% to 75%, for medium and fine sand filling, poor sorting
<3-8-3>	Compact pebble soil	Gray, blue-gray, brown-yellow, dense, saturated, filled with medium fine sand.	Generally the amount of water, good water-rich, high water permeability.	Pebble content of 75%, for medium and fine sand filling, poor sorting

4 Groundwater treatment plan

The groundwater of the site is mainly Quaternary pore diving, and the main aquifer is sandy pebble stratum, which is a moderately complex site for precipitation projects. The groundwater static level of the site is about 3.80~7.30m. The stable water level elevation is 532.65~541.25m. During the flood season, the water table may rise.

4.1 Excavation dewatering design

The main parameters of this excavation dewatering project in the following table 2:

Table 2. Fengxihe Station excavation dewatering parameters summary table.

Fengxihe Station Excavation Dewatering Parameters	Precipitation influence radius R: 1815m;
	Excavation calculation radius: 40.85m;
	Excavation water inflow Q: 22094m3
	Single well water output q: 720m3;
	Number of precipitation wells n: 35 eyes;
	Precipitation well spacing D: 15m;
	Precipitation well depth HW: 42.5m/40m;

The main precipitation well parameters of this project are shown in figure 4:

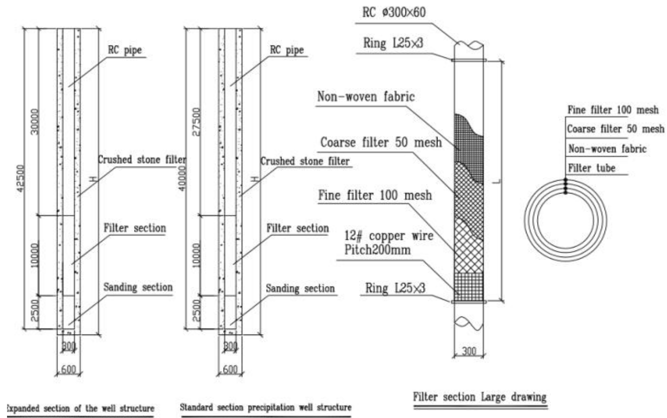

Fig. 4. Structure of the precipitation well.

4.2 Precipitation impact analysis

Excavation precipitation is one of the main factors causing settlement deformation of the surface and surrounding buildings. The buildings around the excavation of Fengxihe Station are densely packed, the underground pipelines are densely covered, the construction site is narrow, and the ground subsidence of the pits will seriously affect the safety of surrounding buildings and underground municipal pipelines. Considering the stratification of the soil, the stratification sum method is used to calculate the settlement caused by the precipitation of the pipe well according to the effective stress increment of the soil. Taking the soil micro-unit of the i-th layer soil, the settlement formula of the i-th layer soil is as follows:

- $\mathrm{L} = \xi \sum_{i=1}^{n} \frac{\Delta P \times H}{E}$,where:
- *L* is the final settlement, mm;
- *δ* is the empirical coefficient for calculating the compressive deformation of the soil layer;
- *ΔP* is the additional stress of the soil layer, kPa;
- *H i* is the thickness of the i-th layer soil, mm;
- *E i* is the i-th layer The compressive modulus of the soil, kPa.

From this, it is calculated that the surface subsidence caused by precipitation at Fengxihe Station is 1~3 mm. Through on-site verification, the surface subsidence caused by construction precipitation in Chengdu sandy pebble stratum is relatively small.

5 Enclosure structure design and construction plan

5.1 Row pile and inner support design

In combination with the geological and hydrogeological conditions of the first phase of Chengdu Metro Line 1 and the requirements for surrounding environmental protection, the selected supporting structure should meet the feasibility of construction, and should also meet the restrictions on the horizontal displacement of the excavationand the surface settlement of the station environment. Finally, it is determined that the envelope structure of Fengxihe Station is a cast-in-place pile. The row pile support form of the deep excavation mainly includes two types: pile and anchor and steel pipe inner support. Bolt support can provide a relatively open working environment for excavation excavation, but due to its relatively poor reliability, the deformation of the excavation is not easy to control, it is restricted by underground pipelines, and easy to have a certain impact on the surrounding pipelines and buildings[3]. In view of the above reasons, the Century Avenue Station does not use bolt support, and the main excavation support is recommended to adopt the plan of row pile and internal support. The site construction photos are shown in figure 5 and figure 6.

Fig. 5. Rotary drilling rig construction.

Fig. 6. Row pile and inner support structure.

The excavation depth of the excavation of the metro station is 28.7~30.0m, and the standard section width is 23.8m. The retaining pile is made of ∅ 1200@1800 size rotary drilling bored pile, the pile length is 34m, and the buried depth of the excavation is or so 6m below. The crown is set at the top of the pile, and the Φ8@150×150 steel mesh is used between the piles. The reinforcement mesh is reinforced by Φ16@600, and the pile is sprayed with 150mm thick C20 concrete. The support structure is provided with five supports vertically. The first support is 800×1000 concrete support, the horizontal spacing is 1.0m, and the second to fifth support is supported by steel pipe with diameter Φ609×16 (t=16mm). The end is supported on the steel cofferdam of the two sides of the retaining pile, the horizontal distance of the steel support is 3m, and the vertical distance of each steel support from the top surface of the first concrete support is shown in figure 7.

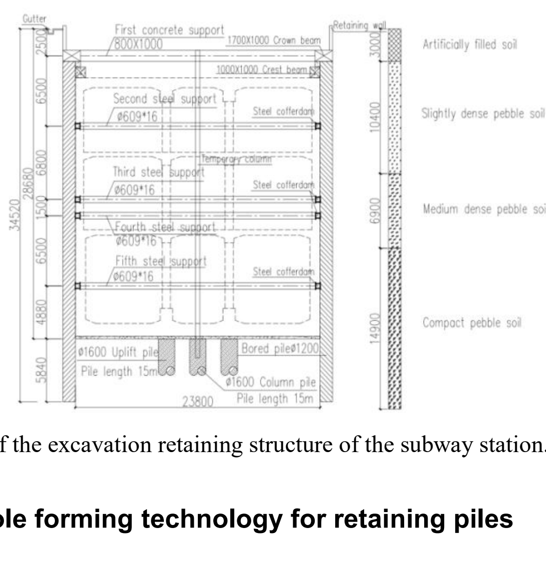

Fig. 7. Sectional view of the excavation retaining structure of the subway station.

5.2 Selection of hole forming technology for retaining piles

By comparing the hole forming process and investigating the hole forming process of the civil excavation and bridge pile foundation near the station, the project is planned to use a rotary drilling rig to form a hole. At the same time, the adaptability of the rotary drilling rig to the soil layer is poor, and the particle size exceeds 0.3 m. The pebble is difficult to drill, and it is difficult to apply to the larger particle size of the pebble stratum or boulders. The following measures are mainly taken during construction[4]:

①The sandy pebble stratum has a large wear on the drill bit, and the drill bit reserve should be increased;

② Large-diameter drifting stone affects the construction of rotary drilling rig, and the ordinary drill bit should be replaced with a spiral drill bit, and the larger-sized boulders must be broken;

③In addition to the expansive soil mud, a certain amount of yellow mud should be stored, if necessary, added to the mud, thereby increasing the mud viscosity, increasing the volume of the mud pool, and increasing the mud reserve to prevent the sandy pebble stratum from leaking and collapsing.

6 On-site monitoring results

During the construction of the station excavation, the construction unit monitored and measured the horizontal displacement of the bored pile top, the inclination of the pile body, the axial force of the steel support, the surface settlement around the excavation, and the groundwater level, and adjusted according to the on-site monitoring results , optimization, to achieve information design[5]. The pit depth of the station is about 28.7~30.0m, and the deformation control protection level is one level. The displacement requirements are:

1) Groundwater level control standard: 2000mm; alarm value: 1600mm.

2) Settlement control standard for surrounding buildings: 20mm; alarm value: 16mm.

Figure 8 shows the groundwater level monitoring points SW03~SW11 within one month that a plot of the distance of the water level from the excavation face, Before the earth excavation, the inner and outer sides of the excavation began to dewater. During the excavation of the excavation, the groundwater level gradually decreased with the increase of the excavation depth, but it remained at 1~2m below the excavation surface of the excavation, which will prevent excessive water head drop .The impact on the surrounding environment is reduced to a minimum. Figure 9 is the cumulative settlement curve of the surrounding building settlement monitoring points JZ1-1~JZ2-12 within one month. The closer to the excavation, the greater the impact. However, they are all controlled within a reasonable range and have little effect on the surrounding buildings and the deformation tends to be stable before the next working condition begins[6].

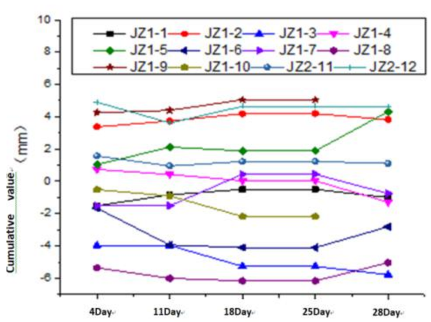

Fig.8. SW03～SW11 water level from the excavation surface distance curve.

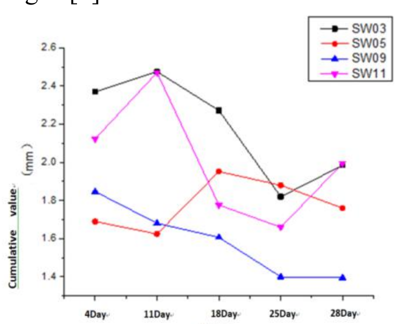

Fig.9. JZ1-1～ JZ2-12 cumulative settlement curve.

7 Conclusion

Through theoretical calculation and actual monitoring results, the design and treatment measures for the excavation of Fengxihe Station in Chengdu metro are safe, feasible and economical. The research on the formation of sandy pebble stratum precipitation measures and hole forming process will provide important technical guarantee for the station design of sand pebble stratum[7]. By comparing the monitoring measurement data with the theoretical analysis results, it is found that the deformation trend of the enclosure structure and the supporting axial force are basically in line with the design expectations, indicating that the design method is reasonable and correct. The main conclusions are as follows:

①Treatment of groundwater in Chengdu water-rich sandy pebble stratum is an effective treatment method for using excavation outer tube well precipitation. According to precipitation settlement analysis and construction monitoring, when fine particles are controlled within the required range, due to the skeletal effect of the sandy pebble stratum, the surface subsidence caused by precipitation is relatively small, and the resulting subsidence value is basically 2 to 5 mm.

②The hole-forming experience of bored piles in Chengdu's water-rich sandy pebble stratum is the process of forming the hole of the station retaining pile. Steel casings shall be used in the top miscellaneous fill soil and plain fill soil sections to ensure the verticality of the enclosure structure and the stability of the top soil. Mud wall is used in the hole forming process, and the mud concentration is increased at the same time. In addition to the expansive soil mud, a certain amount of yellow mud is stored. If necessary, it is added into the mud to increase the mud viscosity, increase the volume of the mud pool, and increase the mud reserve to prevent The sandy pebble stratum leaks and collapses.

References

1. Sun Shuangxiang. Research on the Support Scheme of Deep Excavations of the Provincial Wenlian Station of Chengdu Metro Line 4 [D]. Southwest Jiaotong University, 2012.
2. Jiang Huachun. Stability and Impermeability Analysis of Water-rich Gravel Stratum Retaining Structure [D]. Central South University, 2012.
3. Wu Bing. Study on The Force Law of Row Pile Support Structure in Deep Excavation of Metro Station in Chengdu Area [D]. Southwest Jiaotong University, 2011.
4. Zhou Song. Research on Deformation and Internal Force of Retaining Structure of Deep-supported Piles in Deep Excavation [D]. Chengdu University of Technology, 2017.
5. Cao Haijing. Research on Monitoring Index of Sand Pebble Excavation Deformation in Chengdu Subway [D]. China Academy of Railway Sciences, 2015.
6. Chen Shengjin. Research on Deformation Law of Deep Excavation in Sand and Gravel Stratum of Chunxi Road Station in Chengdu Metro [D]. Chengdu University of Technology, 2011.
7. Liu Zhiyi. Deformation Study and Design Optimization of Excavation Support Structure of Chengdu Metro Station [D]. Southwest Jiaotong University, 2011.