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Zoning design of a deep and large foundation pit adjacent to the Yangtze River in Wuhan

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Abstract: Taking the design of a deep and large foundation pit near the Yangtze River in Wuhan as an example, combining with the complex environment around the foundation pit and considering the development sequence of the construction unit, the work scheme of "zoning design, zoning construction, supporting pile + internal support" is adopted. In order to reduce the influence of foundation pit excavation on adjacent excavation, piles with large diameter and small pile spacing are used as isolation piles. Using 90 deep dewatering Wells and cement mixing pile (local CSM) as water stop curtain, the calculation can meet the requirements of foundation pit dewatering. The existing monitoring data show that the design of the foundation pit is safe, reasonable and economical, which can provide a certain reference for similar projects

Keywords: Complex deep foundation pit, supporting pile + internal support, isolation pile, groundwater treatment, monitoring data.

1. Introduction

With the deepening of urbanization, housing buildings, subways and viaducts are becoming more and more dense, and the foundation pit of the proposed building is close to the subway, underground pipelines and Yangtze River flood barrier, etc. As the scale and depth of foundation pit are getting larger and deeper, how to reduce the impact of excavation of large foundation pit on the surrounding environment, and how to rationally consider the design and construction of foundation pit in combination with the pace of operation and development of construction units are the problems faced by geotechnical engineers and scientific researchers. Based on the large foundation pit adjacent to the Yangtze RIVER in Wuhan, the paper introduces the partition design of foundation pit and the use of isolation piles, which can provide some reference for the design of similar projects.

2. Project Overview

This project is located in the east of Parrot Avenue, south of Parrot Road and west of Qingchuan Avenue, Hanyang District, Wuhan City. The foundation pit covers an area of about 57,000 square meters and has a perimeter of about 1050m. The foundation pit depth is about 13.6-15.6m. Among the 3 towers: Building 1# is 52F, 300 meters high; building 2# is 44F, 220 meters high; 3# building is 35F, 180 meters high, 3 underground floors (basement area of about 169,800 square meters), 3--5F is the commercial building, area of about 100,000 square meters. The surrounding environment is: The boundary line on the west side of the basement of the project plot is about 5m away from the recent impact line of metro line 6 of the parrot avenue, and has entered the safety protection area of rail transit. The south side is a special railway corridor for China Railway Bridge Bureau. Before construction, subway and railway safety assessment is required. The east side of the basement line is about 53 meters away from the foot of the Yangtze River flood prevention dike, which belongs to the government's strict control area in flood season, as shown in Figure 1:

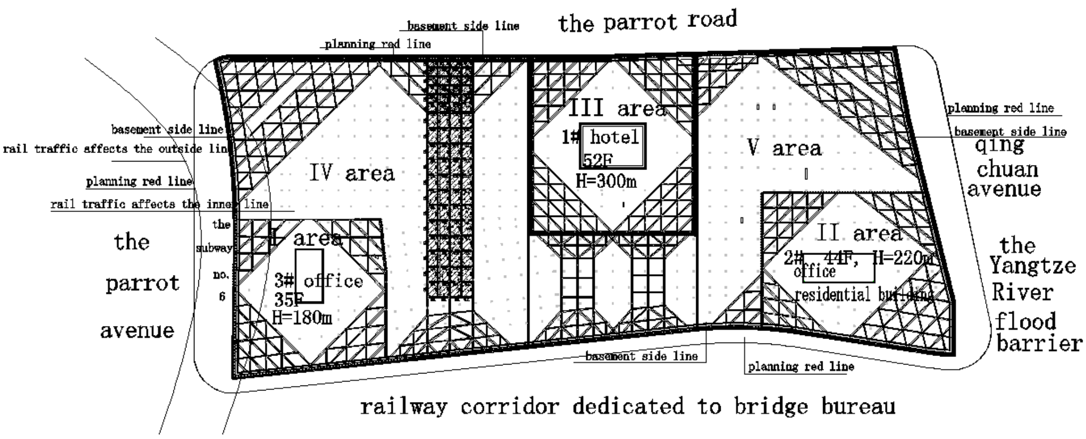


Figure 1. Plan of foundation pit and surrounding environment and partition diagram

Project surface is relatively flat, landform is a Yangtze River terrace. The upper part of the site is clay, and the lower part is sand, which is a typical dual structure. There are three types of ground water: Perched water, pore confined water and bedrock fissure water. Perched stagnant water mainly occurs in the miscellaneous fill soil, and the depth of the water level is 0.2-1.4m. Confined water occurs in the ③silty soil interbed with silty clay and ④silty sand, which is closely related to the hydraulic power of the Yangtze River. The highest confined head is 27.0 m, and the annual variation of the confined head elevation is about 4.0 m. The physical and mechanical properties of the soil layer are shown in Table 1:

Table 1. Physical and mechanical properties of soil layer

Layer number	Name of the soil	The thickness of the soil /m	Bulk density γ kN/m3	Cohesive force c/kPa	Angle of internal friction φ/°	Kv cm/s	K_h cm/s	Bearing capacity f_{ak}/kPa
①	Miscellaneous fill	2.43~6.5	17.5	8	18			40
②	Silty clay	3.50~8.90	17.9	21	12	$3.7x10^{-6}$	$3.7x10^{-6}$	120
③	Silty clay and silt interbedded	4.80~11.1	18.1	10	16	$6.0x10^{-6}$	$4.5x10^{-3}$	110
④	Silt	2.30~10.30	18.3	0	32	$8.6x10^{-3}$	$8.6x10^{-3}$	190
⑤	Silty sand	5.20~11.90	18.5	0	35	$9.7x10^{-3}$	$9.7x10^{-3}$	250

3. Foundation pit partition design strategy

According to the development sequence of the construction unit, the 3# building tower area shall be constructed first, then the 2# building tower area, and finally the 1# building area. Due to the large area and depth of the foundation pit (there are three floors in the basement), the division of the foundation pit should consider the opinions of the construction unit and the location of the tower as far as possible to ensure the owner's requirements and the safety of the foundation pit. The corresponding construction process of foundation pit excavation is as follows: 3# building tower area (I), 2# building tower area (II), 1# building area (III), the west side of foundation pit (IV), the east side of foundation pit (V). In the partition diagram of foundation pit, isolation piles are used to divide the large foundation pit into five small ones, as shown in Figure 1.

4. Foundation pit characteristics and support scheme, waterproof curtain scheme selection

4.1. Characteristics of foundation pit

The excavation area of the foundation pit is large and roughly rectangular， The mechanical properties of the foundation pit are good. Considering that the foundation pit is close to the subway and the Yangtze River (about 53 meters away from the foot of the Yangtze River flood barrier), the groundwater is closely connected with the hydraulic power of the Yangtze River. The foundation pit bottom enters the soil layer ③ and the soil layer ④, and the mechanical properties of the soil layer ③ are poor. When choosing the foundation pit supporting scheme, we must pay attention to meet the safety and economy.

4.2. Selection of foundation pit supporting scheme

(1) soil nailing wall (composite soil nailing) support system

The excavation depth of the foundation pit is about 13.6-15.6m, and the composite soil nailing support is suitable for the condition that the foundation pit is not more than 12m and the underground water is not rich, so the composite soil nailing support is not suitable for the foundation pit.

(2) pile-anchor supporting system

The soil layer of the foundation pit ③ is poor. If the pile anchor support is adopted, the anchorage section of the bolt is located in the poor soil layer, which will be damaged due to insufficient strength, so it is not suitable for the pile anchor support system.

(3) Underground diaphragm wall + inner support

The diaphragm wall has large stiffness and good sealing effect, which can greatly reduce the problem of groundwater leakage. At the same time, the quality of the diaphragm wall scheme is reliable, and the impact on the surrounding environment is small. The horizontal displacement of the diaphragm wall + internal support constraint is less than that of the pile support. However, because the cost of wall + inner support is higher than that of pile support, it is not suitable to use considering the opinions of the construction unit.

(4) Supporting pile + internal support

Due to the good soil quality of the foundation pit, through the reasonable design of supporting pile + inner support, the horizontal and vertical displacement of the foundation pit are respectively within the displacement range controlled by the foundation pit code and the subway code, and will not affect the surrounding buildings, roads, flood control lift, etc., and the cost is lower than the diaphragm wall + inner support. Considering geological conditions, surrounding environment, excavation depth and other factors, in line with the principle of "safe and reliable, economical and reasonable, and technically feasible", pile row + inner support scheme is adopted.

4.3. Scheme selection of water cutting curtain

CSM, TRD and three-axis mixing pile construction methods are used in the deep foundation pit of the first level terrace of the Yangtze River in Wuhan, which can be used separately for the water stop curtain. CSM and TRD have strong ability to adapt to the formation, and can form water cutting wall with good sealing effect. The three-axis mixing pile adopts the sleeve to cut off the water curtain. If the design and construction are reasonable, the water cutting effect is also very good. In the design of the foundation pit, when the buried depth of the sand layer at the bottom is more than 32m (such as part of the north and west of the foundation pit), in order to prevent the foundation pit from surging, CSM sealing process is adopted in areas with high groundwater level, and the rest of the pit is used as the sealing curtain.

5. Foundation pit supporting design

5.1. Supporting pile design

Due to the large excavation depth of the foundation pit, the foundation pit bottom is located in the interlayer ③ of silty clay and silt interbedded and ④ of silt. The soil layer ③ has poor mechanical properties and the surrounding environment is complex, so the diameter of supporting piles is generally large. For example, the clear distance from the west side of the foundation pit to the subway is about 5m. In order to ensure the safety of the foundation pit and not affect the normal operation of the subway, the surface overload is calculated by 25kPa and Tianhan software. The diameter of supporting pile is 1.2m, the pile spacing is 1.5m, and the pile length is 23.10m, as shown in Figure 2.

In the tower area, the foundation pit is first excavated, taking tower 1 as an example for analysis. The tower is located inside a large foundation pit with an internal surface elevation of 23.0m. Due to the slope space, slope release and load reduction is set on the top of the crown beam, which can reduce the active earth pressure of the supporting pile and reduce the pile diameter. The diameter of the supporting pile is 1.0m, the pile spacing is 1.4m, and the pile length is 22.1m, as shown in Figure3.

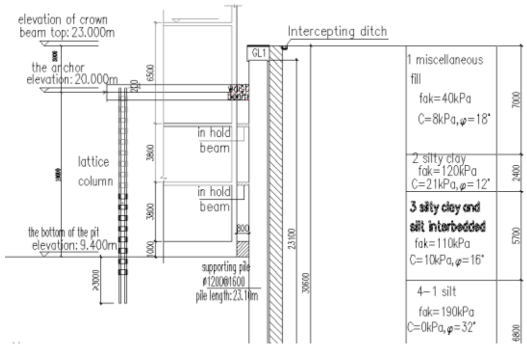


Figure 2. HH1 profile support

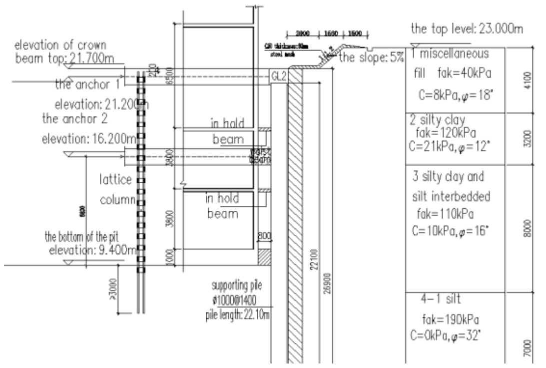


Figure 3. 1# tower foundation pit

5.2. Internal support design

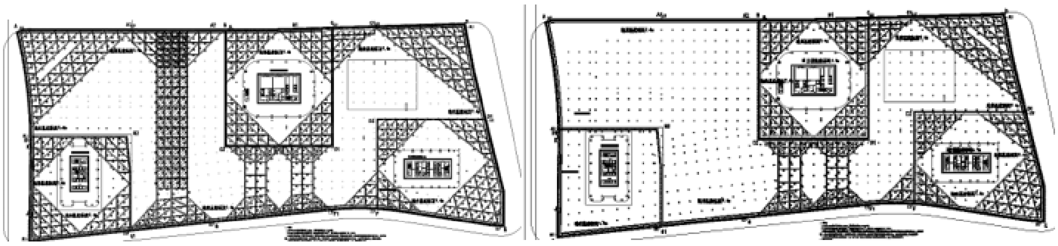
Due to the large area of the foundation pit, the top support is set in the west of the foundation pit, and the corner support is set in the corner of the large foundation pit. For the isolation pile of Tower 1#, the distance from the relatively large foundation pit is far (55.26m), so two short roof supports are set up. According to the Code for Building Foundation Pits, the spacing of internal supports cannot exceed 9m, so pipa supports with a certain spacing are set between the tower and the surrounding foundation pits. There are two inner supports in the middle and east of the foundation pit. In order to facilitate the setting of lattice columns, the layout of the two inner supports is very close. Due to the different reaction forces acting on the two supports, the section size and reinforcement of the corresponding supports are also different.

Since the surface elevations of foundation pit area, I and area IV are 23.0m and the base elevations of foundation pit are 9.4m (both absolute elevations), an inner support is set; In the other three areas, the surface elevation is 24.0m-25.0m, and area II, III and V respectively adopt two inner supports. The inner support scheme is divided into two forms: supporting pile + top support (concurrently used as trestle) and supporting pile + Angle support, as shown in Figure 4. Due to the large area of the foundation pit, in order to facilitate the transport of soil, the use of the top support set up the lane thick plate, and play the role of construction trestle.

5.3. Groundwater control design

For confined water in ③ silty clay and silt interbedded and ④ silty sand beds, a combination of middle-deep well drainage precipitation and decompression precipitation is used to treat the confined water. Lower groundwater standards: groundwater is lowered to 1m below the bottom of the foundation pit. After calculation and optimization, a total of 90 dewatering Wells are arranged in the foundation pit. The base elevation of the 1# tower is 6.9m, and nine precipitation

Wells are arranged. The base elevation of 2# tower is 6.9m, and the base elevation of 3# tower is 7.4m. Four 4 precipitation wells are arranged for each. The design depth of the precipitation well is 30m, the pipe diameter is 300mm, and the water yield of a single well can reach 1440T/D.



a) the first inner support b) the second inner support

Figure 4. Layout plan of inner support

6. Analysis of monitoring results

Due to the financial constraints of the project, Tower 3 (area I) is currently under construction and has monitoring data, the monitoring graph is shown in Figure 5. The monitoring contents of area I include: horizontal and vertical displacement of pile top (crown and beam top) (12), settlement observation of surrounding buildings and roads (9), deep soil displacement monitoring (4), axial force monitoring (8), and column settlement observation (8). From excavation to backfilling in I area of foundation pit, the top displacement and numerical value of crown beam and the displacement of surrounding roads do not exceed the allowable requirements, as shown in Table 2:

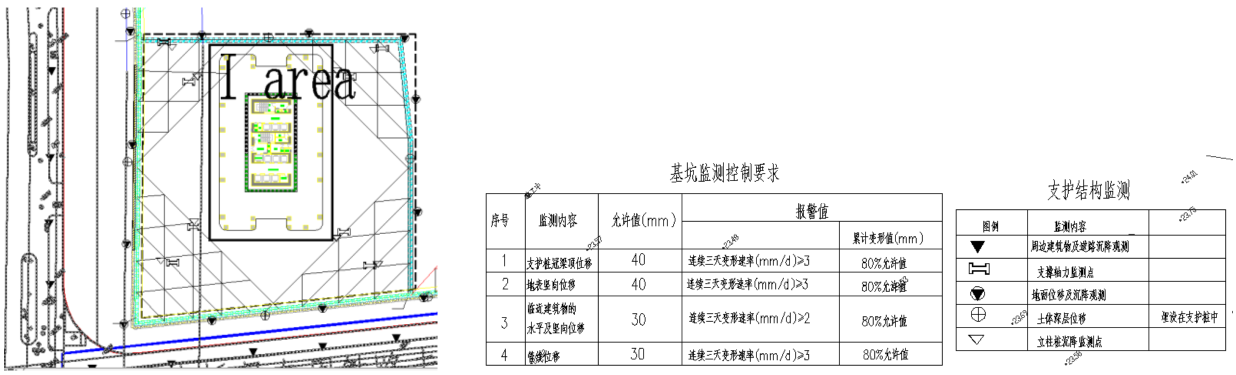


Figure 5. Monitor graphics and control requirements

Table 2. Table of monitoring results for Tower 3# (area I)

number	monitoring content	minimum value	maximum value	the average
①	horizontal displacement of pile top	17.7mm	20.3mm	19mm
②	vertical displacement of pile top	19.2mm	25.6mm	22.4mm
③	surrounding road settlement	11.3mm	14.1mm	12.7mm
④	deep soil displacement	20.4mm	24.8mm	22.6mm
⑤	strut axial forces	547kN	1132kN	840kN
⑥	settlement of lattice columns	10.6mm	17.2mm	13.9mm

As can be seen from Table 2, the monitoring results of area I do not exceed the requirements of "Technical Specifications for Building Foundation Pit Engineering Monitoring" (GB50497-2009). The west side of the foundation pit in Area I is very close to the range line of the rail transit protection area, and the data in Table 2 does not exceed the Technical Specifications for Urban Rail Transit Engineering Monitoring, it shows that the design of foundation pit in area I is safe and reasonable.

7. Conclusion

Through the partition design and construction scheme of the super large foundation pit with complex surrounding environment and adjacent to the Yangtze River, the safety of the foundation pit itself should be ensured, and the normal operation of the surrounding rail transit should be ensured and the flood control requirements of the Yangtze River should be met. On the premise of satisfying the safety and economy of the foundation pit, the waterproof curtain scheme of supporting pile + top support, corner support and set type cement mixing pile (local CSM) is adopted. The existing monitoring data show that the design of the foundation pit is safe, economic and reasonable,the design of foundation pit can provide some reference for similar projects.

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Biography

Wang Ruifang, Doctor, associate professor, master supervisor, mainly engaged in geotechnical engineering teaching and research.