Exploration of Deep Foundation Pit Support Scheme for Super High-Rise Buildings with "Two Walls in One, Two-Way Support System" in Complex Subway Environments

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Abstract: In order to solve the problem of deep foundation pit support for existing super high-rise residential buildings with complex surrounding environments and high protection requirements, such as subway entrances and exits, subway section tunnels, and river channel relocation culverts and pipelines, we explore the use of an underground continuous wall "double wall combined with four reinforced concrete supports" setting scheme, and adopt a first level deep foundation pit support scheme combining diagonal braces and braces. Based on the selected plan, 10 typical soil profiles and 1 underground connecting channel profile around the foundation pit were selected. According to 17 working conditions, the elastic foundation beam theory was used, and the internal force values, displacement, overall stability safety factor, wall bottom anti uplift safety factor, and pit bottom anti uplift safety factor of the underground continuous wall, support and plate were calculated using Qimingxing V8.2. The calculation structures of different profiles were compared and analyzed, and some were verified using Lizheng Deep Foundation Pit 7.0. The calculation results of the two software were in good agreement and could meet the requirements of the specifications. The calculation conclusions and support schemes of the article provide numerical references for similar deep foundation pit projects.

Keywords: Near Subway Deep Foundation Pit; Support Technology; Underground Continuous Wall; Reinforced Concrete Support; Internal Force Calculation; Safety Factor

1 Introduction

In the process of continuous urbanization, urban land resources are relatively limited, and expanding new urban spaces up and down has become the optimal choice for urban construction. [1] With the development of transportation systems, a series of commercial complexes have emerged near a large number of newly built subways, resulting in some deep foundation pit projects. The construction of foundation pits has become increasingly complex, and the difficulty of deformation control has also increased. [2]In recent years, due to various reasons, safety accidents in deep foundation pit engineering have occurred frequently in various parts of China. These accidents not only affect the construction period, but also increase the cost, causing huge economic losses to all parties involved in the construction. They have had a negative impact on society and posed new problems and challenges to the excavation and support technology of deep foundation pits.[3]

The selection, calculation, and exploration of deep foundation pit support schemes adjacent to subways, rivers, municipal roads, and residential areas provide theoretical references for similar projects and have practical engineering significance.

2. Current Research Status at Home and Abroad

Domestic and foreign scholars have conducted extensive research on the design of deep foundation pit support schemes, providing theoretical support for engineering practice and accumulating valuable experience.

Domestic scholar Li[4] analyzed the on-site monitoring data of a foundation pit with multiple support methods, taking the deformation of the retaining structure and the settlement of the surface soil outside the pit as examples, to study the influence of different support structures on the spatial effect of the foundation pit under the same conditions [4]. Ma [5] established a three-dimensional numerical calculation model of the foundation pit to study the settlement of buildings at different positions and heights around the pit during the construction process. By changing the excavation and support methods of the pit, the spatial deformation of the pit was analyzed and compared with the measured data, providing reference for pit construction [5]. Li [6] conducted indoor model tests to study the deformation and internal forces of the retaining structure of a deep foundation pit. During the construction process, the maximum displacement of the supporting wall increased and the location where the maximum displacement occurred also shifted downwards [6].

Foreign scholars and Iranian scholars Reza [7] conducted research on the horizontal displacement and support methods of urban deep foundation pits. The minimum and maximum depths of the excavation were 26 meters and 45 meters, respectively, using three different support systems. Due to the lateral movement limitations of adjacent buildings, precise instruments are used to control the displacement of excavated walls during and after construction, and the actual displacement is compared with the displacement predicted by numerical analysis [7]. Houhou [8] studied the excavation of foundation pits using anchor rods and underground continuous walls for support. Bolton [9] conducted model experiments simulating excavation of foundation pits indoors, studying the distribution patterns of displacement of support structures, soil displacement before foundation pit instability, and settlement of surrounding soil outside the pit. They further analyzed the working performance of underground continuous walls and the interaction mechanism between support structures and soil.[9] Bryson [10] studied the impact of deep excavation in soft soil areas on surrounding buildings and found a functional correspondence between support structure cracking and building self weight pre settlement.

Research on structures both domestically and internationally provides theoretical references for the selection and design of support structures for super high-rise deep foundation pits in complex environments.

3. Calculation Theory of Deep Foundation Pit Support

(1) Calculation mode

According to the specifications [11], the calculation of underground continuous walls under temporary construction conditions adopts the vertical elastic foundation beam method ("m" method). The elastic foundation beam method takes a retaining wall of unit width as the vertically placed elastic foundation beam, and simplifies the support into spring elements related to cross-sectional area, elastic modulus, and calculated length. The compression spring stiffness K_H [11] of the horizontal spring support below the excavation surface or ground level of the foundation pit can be calculated according to the following formula:

$$K_H = k_h bh \tag{1}$$

$$k_h = mz \tag{2}$$

In the formula, K_H is the compression stiffness of the soil spring (kN/m); K_h is the horizontal coefficient of the foundation soil (kN/m^3); m is the proportional coefficient of the coefficient; z is the depth from the excavation surface; b. Calculate the spacing (m) between the horizontal and vertical directions of the spring, denoted as h.

The stiffness of the support in the foundation pit is related to the arrangement of the support system and the material of the support components, as well as the axial stiffness and other conditions. It is calculated according to the following formula [11]:

$$K = \frac{2\alpha EA}{LB} \tag{3}$$

In the formula: K - stiffness coefficient of internal support (kN/m/m);

α ——The reduction factor related to support relaxation is generally taken as 0.5-1.0; When applying pre pressure to concrete or steel supports, take 1.0;

E - elastic modulus of supporting component material (kN/m^2); A - cross-sectional area of supporting components (m^2);

L - calculated length of support (m); B - Horizontal spacing of supports (m).

(2) Water and soil pressure

The standard value of the active soil pressure strength of the i-th layer of soil at depth z is

calculated according to the following formula:
When using the method of combining water and soil or calculating points above the water level [11]:

$$p_{ak} = (q_0 + \sum_{j=1}^{i} \gamma_j \Delta h_j) K_{a,i} - 2c_i \sqrt{K_{a,i}} \quad (4)$$

$$K_{a,i} = \tan^2(45^\circ - \varphi_i/2) \quad (5)$$

(Less than 0, take 0)
When using soil and water separation calculation and the calculation point is below the water level [11]:

$$p_{ak} = \left[q_0 + \sum_{j=1}^{i} \gamma_j \Delta h_j - (z - h_{wa,i}) \gamma_w \right] K'_{a,i} - 2c'_i \sqrt{K'_{a,i}} \quad (6)$$

$$K'_{a,i} = \tan^2(45^\circ - \varphi'_i/2) \quad (7)$$

(Less than 0, take 0)
For the rectangular soil pressure mode, the self weight of the soil in the pit must be deducted from the self weight (for the soil layer below the water level, the effective self weight is deducted; the water level in the pit is taken from the bottom of the pit, and the natural water level is taken below the bottom of the pit). In the formula:
γ_j —The natural weight of the j-th layer of soil; γ_w —The weight of water is taken as 10kN/m^3;
Δh_j —Thickness of the jth layer of soil; $h_{wa,i}$ — Groundwater level;
c_i c'_i —Cohesion and effective cohesion of the i-th layer of soil; φ_i φ'_i —The internal friction angle and effective internal friction angle of the i-th layer of soil;
q_0 – Uniformly distributed additional load standard value;

4. Project Overview

(1) Overview of foundation pit
A 147m super high-rise tower is planned to be built on the site of this project, with a roughly shuttle shaped plan. It is located in the northwest corner of the site, with 34 floors above ground, mainly used for hotel offices. The project generally has 4 basement floors. The project consists of two foundation pits: the basement main foundation pit and the south external lane foundation pit. The total area of the basement main foundation pit is about 18000 square meters, and the total length of the surrounding area of the foundation pit is about 627 meters; The total area of the external lane foundation pit is about 980 square meters, and the total length of the surrounding area of the foundation pit is about 235 meters. The elevation of the bottom plate of the main basement structure is -19.250m.
The surrounding buildings and roads of the proposed site are densely distributed. The excavation boundary of the foundation pit is about 5.7m to 24.1m away from the north land red line. The outer side of the red line is the municipal road Guanshan Road, with a width of about 45.0m. Outside the pit, from far to near, are the main body of the operating Rail Transit Line 1 station, the section tunnel, the municipal pipeline under Guanshan Road, the No. 3 and No. 2 entrances and exits of the subway station, and the 1.2m diameter culvert pipe used for temporary relocation and river drainage.
(2) Difficulties in foundation pit support
The depth of the foundation pit is large, with a maximum excavation depth of 22.05 meters. There are entrances and exits of subway line 1 stations, subway section tunnels, municipal road pipelines, temporary relocation and drainage culverts for rivers, and residential basements in the surrounding area. Moreover, the distance between the foundation pit and these environments is relatively close. If the supporting structure fails or undergoes excessive deformation, it will have a huge impact on the surrounding environment. Therefore, foundation pit support is relatively difficult.

5. Selection of Deep Foundation Pit Support Scheme

Based on the engineering geological conditions such as topography, geological composition and features, hydrogeological conditions, adverse geological conditions, and site geological conditions, the excavation depth of the basement main foundation pit of this project is 19.85m to 22.05m, and the surrounding environment is complex. According to the specifications [11], it belongs to the first level safety level foundation pit engineering. Therefore, considering the characteristics of this project and the requirements of surrounding environmental protection, based on calculation analysis and engineering practice experience, this

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foundation pit project plans to adopt the layout form of "two walls in one, with four reinforced concrete braces and corner braces combined".

(1) Horizontal support system

There are two main forms of horizontal support: reinforced concrete support and steel support. [12]Steel supports have limited stiffness and are usually suitable for underground basement excavations from the first to the second floor, and are not suitable for use in deep excavations. At the same time, steel support rods generally cannot directly bear dynamic loads, so using a steel support system requires the establishment of a construction wharf independent of the support rods, which increases the project cost to a certain extent. Considering the large excavation area and excessive depth of the foundation pit in this project, as well as the high environmental protection requirements in the surrounding area, the steel support scheme is not feasible. Reinforced concrete internal support has the characteristics of high stiffness and small deformation, which plays an important role in reducing the horizontal displacement of the enclosure structure and ensuring its stability. At the same time, concrete support construction has strong adaptability and can be applied to various complex shapes and large excavation areas of foundation pit projects. Therefore, this project adopts reinforced concrete support. Strengthen the strength and stiffness of the support in the vicinity of the subway area in the plane layout, and minimize the deformation of the enclosure structure to reduce the impact on the surrounding environment, as shown in Figure 1.

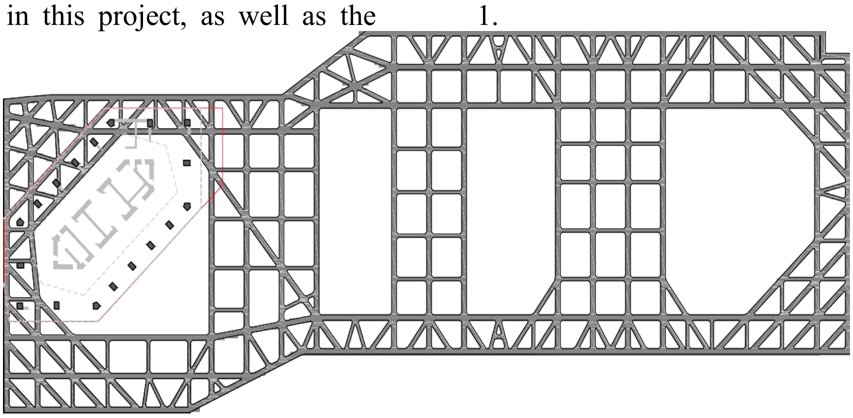

Figure 1. Support Layout

The general excavation depth of this foundation pit project is 20.45m, and the excavation depth of the tower area is 22.05m. The strength grade of the first supporting concrete is C35, and the strength grade of the second to fourth supporting concrete is C40. The thickness of the protective layer is 30mm. The cross-sectional dimensions, strength grade, and center elevation of the supporting rod are shown in Table 1.

Table 1. Supporting Section Information (Unit: m)

Number	Relative elevation	number	Top beam/purlin support	angle brace	splayed bracings	connecting rod
The First track	-1.700	C35	1.1×0.8	1×0.8	0.8×0.7	0.7×0.6
The second track	-7.200	C40	1.4×1.1	1.3×1.0	1.0×0.8	0.8×0.6
The third track	-12.200	C40	1.6×1.2	1.3×1.0	1.0×0.8	0.8×0.6
The fourth track	-16.700	C40	1.4×1.1	1.2×0.9	0.9×0.7	0.7×0.6

(2) Vertical support system

The vertical support system adopts the form of drilled cast-in-place piles with inserted angle steel lattice columns [12]. The concrete strength grade is underwater C30, and the angle steel material of the lattice columns is Q355B grade. The engineering properties of the soil layer below the base of the site are generally average, and the standard values of the ultimate lateral resistance and ultimate end resistance of the cast-in-place pile are relatively low.

In the support area, the diameter of the cast-in-place pile is 900mm, and the length of the pile in the area with lower load (opposite support area) is 33.0m. The bearing layer is located in the silt mixed with silty clay, and the characteristic value of the single pile bearing capacity is 2600kN. The corresponding grid column specification is 4L160 × 16, and the cross-sectional size is 460 × 460; the pile length in the heavily loaded area (corner brace region) is 55.0m, with a bearing layer of silty clay. The characteristic value of the single pile bearing capacity is 3900kN, and the corresponding grid column specification is 4L180 × 18, with a section size of 480 × 480.

6. Calculation of Deep Foundation Pit Support Scheme

(1) Calculation conditions

This project selects 11 typical soil profiles around the foundation pit, and the profile information is shown in Table 2, including one underground connecting passage profile. There are significant differences in the distribution of water and soil pressure outside the basement of the main structure, as well as the constraint conditions of internal support or main structure beams and slabs on the underground continuous wall. This results in different boundary conditions for wall calculations during the construction and use phases. Therefore, it is necessary to calculate the stress on the underground continuous wall separately for each phase. The following calculation only includes the force and deformation calculation of the foundation pit enclosure under the implementation conditions of the foundation pit.

The calculation of the foundation pit enclosure adopts the vertical elastic foundation beam method, and the c and φ values of the soil are based on the parameter indicators provided in the survey report. The deformation, internal force calculation, and stability verification of the enclosure are based on the principle of water and soil integration for cohesive soil, and separate calculation for sand and silt. In the calculation, an additional load of 20 kPa is uniformly distributed for ground construction. In the calculation of the support system, the support and purlin are treated as a whole, and internal forces and reinforcement calculations are carried out according to the finite element analysis of the planar rod system.

Table 2 Different Profile Information

Serial number	Calculation profile	Location	Number	Wall thickness (m)	Excavation depth (m)	Insertion depth (m)	Environmental level	region
1	1	North side of foundation pit	CB3	1.0	20.45	29.0	one-level	foundation platform
2	2	North side of foundation pit	JB17	1.0	20.45	29.0	one-level	foundation platform
3	3	North side of foundation pit	JCB7	1.0	20.45	29.0	one-level	foundation platform
4	4	East side of foundation pit	CB43	0.8	20.45	29.0	one-level	foundation platform
5	5	South side of foundation pit	CJB16	0.8	20.45	29.0	one-level	foundation platform
6	6	South side of foundation pit	CB31	0.8	20.45	29.0	one-level	foundation platform
7	7	South side of foundation pit	CB33	0.8	20.45	29.0	one-level	foundation platform
8	8	West side of foundation pit	CB34	1.0	20.45	29.0	one-level	foundation platform
9	1A	North side of foundation pit	CB3	1.0	22.05	29.0	one-level	foundation platform
10	8A	West side of foundation pit	CB34	1.0	20.45	29.0	one-level	foundation platform
11	9	West side of foundation pit	CJB16	0.8	8.95	10.5	second-level	External lane

(2) Calculate operating conditions

Taking section 1, which is the general location on the north side of the foundation pit with hole number CB3, as an example, horizontal concrete support is constructed layer by layer from top to bottom. When reaching the bottom layer, the cushion layer and foundation bottom plate are poured in a timely manner, and replacement support components are constructed. After the construction of the horizontal support components is completed, the concrete supports are dismantled layer by layer, divided into blocks, balanced, and symmetrically in a bottom-up order. The vertical components of each layer are constructed upwards, and the beams and slabs of each layer are poured and the support components are replaced. The specific calculation process and working conditions are shown in Figure 2.

(3) Calculate parameters

1) Soil layer parameters

Through engineering investigation, the proportional coefficients of the name, thickness, cohesion, internal friction angle, and horizontal reaction coefficient of each soil layer are obtained as shown in Table 3.

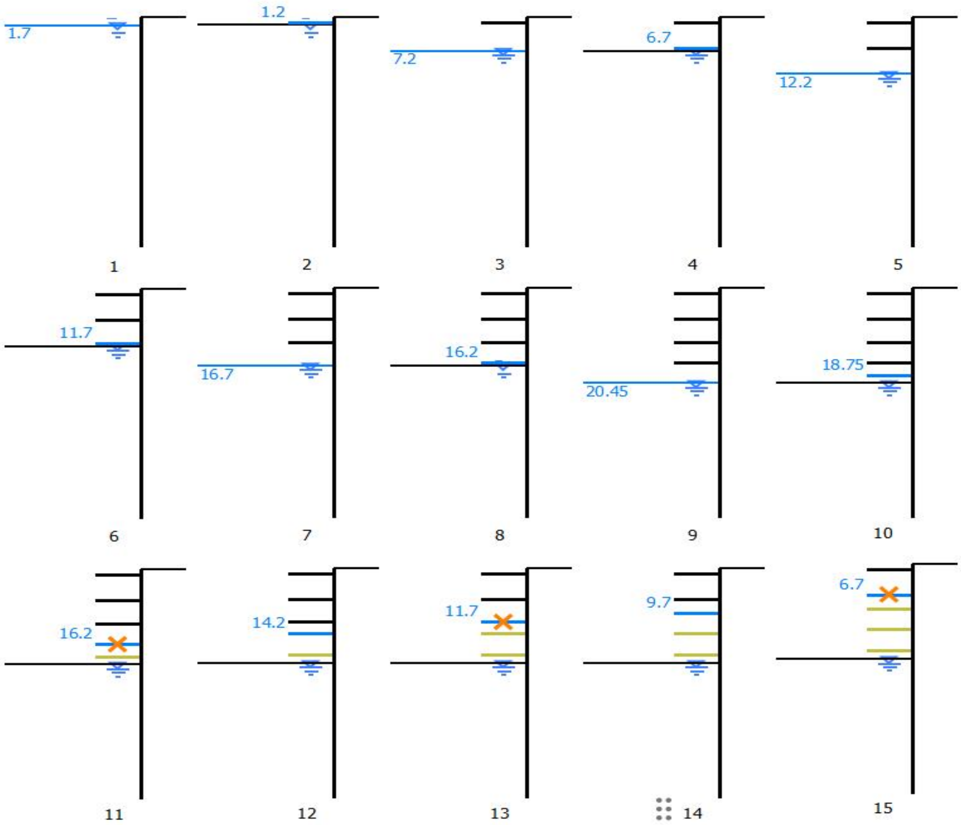

Figure 2. Schematic Diagram of Working Conditions

Table 3 Soil Layer Parameters

Number	Soil Layer Name	Thickness (m)	capacity (kN/m3)	c (kPa)	φ (°)	Separated and taken together caculation	M (MPa/m2)
1-2	Filling clay	3.26	19.3	15	10	separated	1.5
2	Clay	3.3	19.9	55.2	14.6	together	5
3-1	Silty clay	2.7	19.4	26.5	13.9	together	3.5
3-2a	Silty clay	1	19.2	17.2	16.3	together	2.5
3-2	Sandy silt	3.9	19.3	11.5	21.5	separated	4.5
3-3	Silty clay	2.3	18.6	19.3	12.2	together	2
4-2	Clay	6.8	20.3	54.5	14.6	together	6
5-1	Silty clay	8	19.6	31.7	14.3	together	4.5
5-2	Silty clay	3.2	19.1	23.6	14	together	3
5-2T	Sandy silt	3.7	19.7	7.7	30.3	separated	6
5-2	Silty clay	2.3	19.1	23.6	14	together	3
6-1	Silty clay	7.1	19.7	30.8	14.6	together	5
6-2	Clay	3.3	20.5	46.5	15	together	6
7-1	Sandy silt	8	19.3	13.8	21.6	separated	6
7-2	Sandy silt	4	18.8	19.9	17.6	separated	5
8	Silty clay	4.6	18.7	23	13.8	together	4.5
9-1	Silty clay	8.8	20.2	30	15	together	5

2) Load

The ground working load is 20kPa.

3) Retaining wall

The retaining wall is an underground continuous wall with an embedded depth of 29m, a thickness of 1m, and a concrete strength of C35.

4) Support and anchor rods

The support and anchor parameters are shown in Table 4.

(4) Calculation results

Using Qimingxing V8.2 for calculation, some profiles were validated using Lizheng Deep Foundation Pit 7.0. The calculation of CB3 hole on the north side profile is as follows:

Table 4 Support and Anchor Rod Parameters

Number	Depth	Support Stiffness K(MN/m2)	Type
1	1.2	80	inner support
2	6.7	100	inner support
3	11.7	100	inner support
4	16.2	90	inner support

1) Schematic diagram

The design depth of the foundation pit is 20.45m, and the safety level of the foundation pit is level one, as shown in Figure 3.

2) Deformation and Internal Force Envelope Diagram

Calculate the displacement, bending moment, and shear force values at different heights, and plot the envelope diagram as shown in Figure 4.

3) Overall stability verification

As shown in Figure 5, H=20.45m, K=1.84, meeting the requirements of the specifications.

4) Calculation of uplift at the bottom of the pit

The calculation results of the uplift at the bottom of the pit are shown in Figure 6.

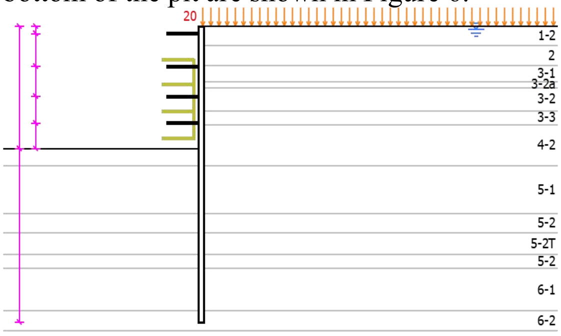

Figure 3. Calculation Diagram

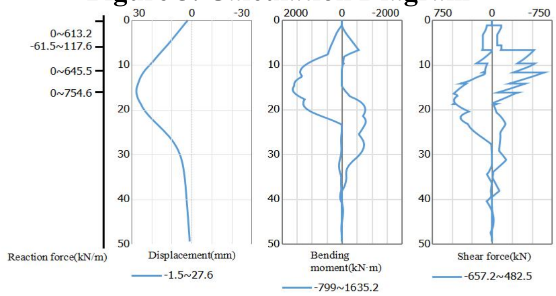

Figure 4. Deformation and Internal Force Envelope Diagram

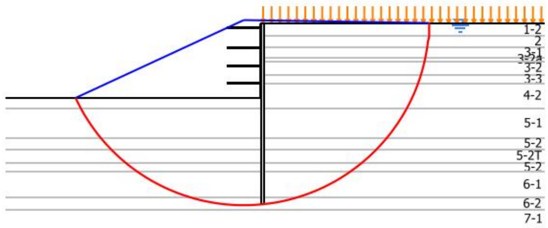

Figure 5. Overall Stability

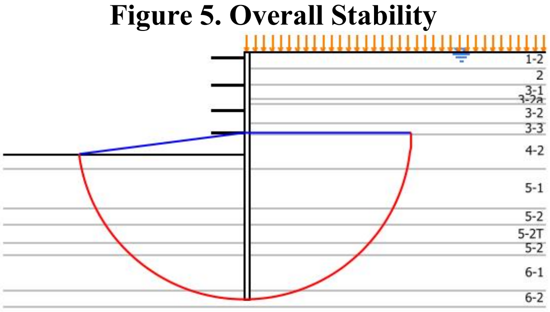

Figure 6. Pit Bottom Uplift

The depth of the pit bottom is H=20.45m, the safety factor is K=2.4, and the standard requirement is 2.2, which meets the requirements.

5) Calculation of wall bottom uplift

layer of soil 6-2

$$\varphi=15^{\circ},\ c=46.5kpa, K=\frac{\sigma_p N_q+cN_c}{\sigma_\alpha}=\frac{570.4\cdot3.94+46.5\cdot10.98}{989.6}=2.79$$

layer of soil 7-1

$$\varphi=21.6^{\circ},\ c=13.8kpa, K=\frac{\sigma_p N_q+cN_c}{\sigma_\alpha}=\frac{599.3\cdot7.51+13.8\cdot16.44}{1018.5}=4.64$$

layer of soil 7-2

$$\varphi=17.6^{\circ},\ c=19.9kpa, K=\frac{\sigma_p N_q+cN_c}{\sigma_\alpha}=\frac{753.7\cdot5.06+19.9\cdot12.79}{1172.9}=3.47$$

layer of soil 8

$$\varphi=13.8^{\circ},\ c=23kpa, K=\frac{\sigma_p N_q+cN_c}{\sigma_\alpha}=\frac{828.9\cdot3.52+10.25}{1248.1}=2.53$$

layer of soil 9-1

$$\varphi=15^{\circ},\ c=30kpa, K=\frac{\sigma_p N_q+cN_c}{\sigma_\alpha}=\frac{914.9\cdot3.94+30\cdot10.98}{1334.1}=2.95$$

The above safety factors are all greater than 1.8, meeting the requirements.

7. Calculation results of different profiles

The calculation process for the other 10 profiles is the same as profile 1. The maximum positive and negative bending moments, maximum positive and negative shear forces, four support confining pressures, four plate confining pressures, maximum displacement, and safety factor variation curves of 11 profiles are shown in Figures 7-12.

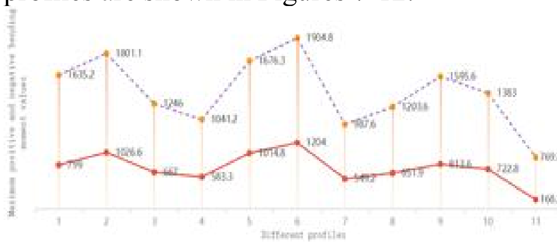

Figure 7. Maximum Positive and Negative Bending Moments at Different Cross-Sections

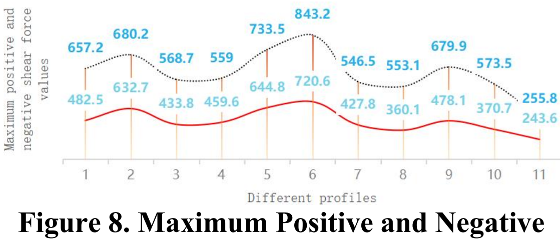

Figure 8. Maximum Positive and Negative Shear Forces at Different Cross-Sections

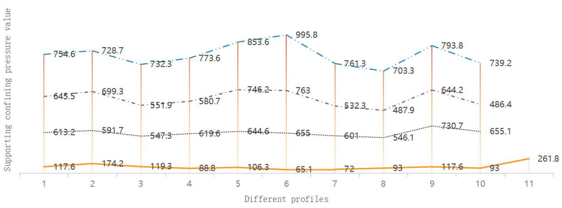

Figure 9. Supporting Confining Pressure Values for Different Cross-Sections

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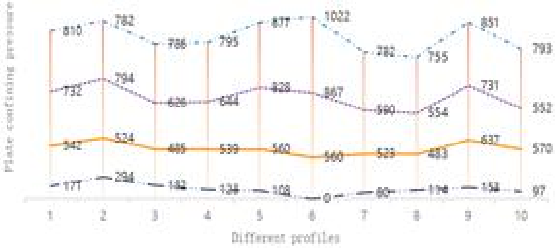

Figure 10. Different Cross-Sectional Panel Confining Pressure Values

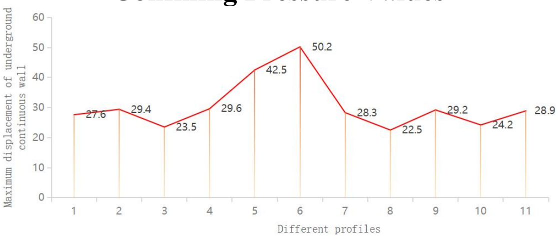

Figure11. Maximum Position of Underground Continuous Wall in Different Sections

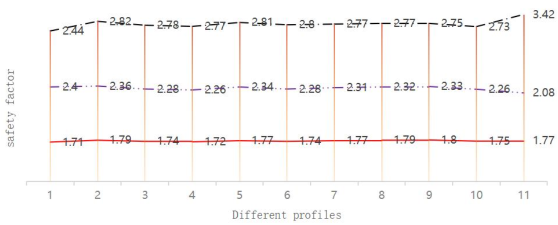

Figure 12. Safety Factors for Different Profiles

From Figure 7 to Figure 12, it can be seen that:

1) In Figure 7 the sequence is negative-positive, from this figure, it can be seen that for the same section, the positive bending moment of each section is greater than the negative bending moment. Among them, the maximum positive and negative bending moments are all on the sixth section, and the maximum positive bending moment value is $1904.8kN \cdot m/m$; The maximum negative bending moment value is $1204kN \cdot m/m$. Therefore, in the reinforcement calculation, special attention should be paid to the sixth section to prevent bending and damage due to insufficient strength.

2) In figure 8 the sequence is negative-positive, according to Figure 8, for the same section, the negative shear force of each section is greater than the positive shear force. Among them, the maximum positive and negative shear forces are all on the sixth section, and the maximum positive shear force value is $720.6kN/m$; The maximum negative shear force value is $843.2kN/m$; Therefore, when calculating reinforcement, special attention should be paid to the sixth section to prevent shear failure due to insufficient shear capacity.

3) In figure 9 the sequence is the third--the second--the fourth--the first, from Figure 9, it can be seen that in the same section, the order of supporting confining pressure values from small to large is the first, fourth, second, and third lines, with the first line being the smallest and the third line being the largest. In different profiles, the maximum value of the first confining pressure occurs on the 11th profile, with a value of $261.8kN/m$; The maximum value of the second confining pressure occurs on the fifth profile, with a value of $764.2kN/m$; The maximum value of the third confining pressure occurs on the sixth profile, with a value of $995.8kN/m$; The maximum value of the fourth confining pressure occurs on the ninth profile, with a value of $730.7kN/m$, therefore, the sixth profile of the third confining pressure is the maximum value.

4) In figure 10 the sequence is B3--B2--Bottom--B1,from Figure 10,it can be seen that in the same section, the order of the confining pressure values of the plates from small to large is B1 plate, bottom plate, B2 plate, and B3 plate, that is, B1 plate has the smallest confining pressure value and B3 plate has the largest confining pressure value; In different profiles, the maximum confining pressure of B1 plate occurs on the second profile, with a value of $294kN/m$, and the maximum confining pressure of the bottom plate occurs on the ninth profile, with a value of $637kN/m$; The maximum confining pressure of B2 plate occurs on the 6th profile, with a value of $867kN/m$; The maximum confining pressure of B3 plate occurs on the 6th profile, with a value of $1022kN/m$;. Therefore, B3 board has the highest confining pressure value and should be given special attention.

5) According to Article 6.2.4 of the "Technical Standards for Monitoring of Building Foundation Pit Engineering" [12], it is known that the maximum horizontal displacement value of the underground continuous wall for profiles 1, 2, 3, 9, and 11 is 30mm; The maximum horizontal displacement of profiles 4, 5, 6, 7, 8, and 10 is 60mm; According to Figure 11, the maximum displacement is at the 6th section with a value of 50.2mm, followed by the 5th section with a value of 42.5mm, both of which meet the requirement of a horizontal displacement limit of 60mm; At the same time, as shown in the figure, the

horizontal displacement values of other sections meet the requirements of the horizontal displacement warning value in specification [12].

6) In figure 12 the sequence is bottom of the wall --bottom of the pit--global stability, figure 12 includes three safety factors: overall stability, anti uplift at the bottom of the pit, and anti uplift at the bottom of the wall. According to the Technical Regulations for Building Foundation Pit Support, the overall stability safety factor of the profile is not less than 1.3, the anti uplift safety factor at the bottom of the pit is not less than 1.9, and the anti uplift safety factor at the bottom of the wall is not less than 1.6. According to the curve graph, the calculated values of the three safety factors for the 11th profile are 1.77, 3.42, and 2.08, respectively, all of which meet the minimum safety factor requirements of the specifications; The overall stability of the remaining sections of the wall, the resistance to uplift at the bottom of the pit, and the minimum safety factor for the resistance to uplift at the bottom of the wall are 1.35, 1.8, and 2.2, respectively. According to Figure 12, the safety factors of sections 1-10 meet the requirements, and later monitoring found that the monitoring values also meet the regulatory requirements.

8. Conclusion

Through calculation, it was found that the support scheme of "two walls in one, two-way support system" meets the requirements of deep foundation pit support for complex environment super high-rise buildings, which are adjacent to subway entrances and exits, subway section tunnels, and river channel relocation culverts on the north side, subway entrance and exit No. 3 on the northwest side, municipal road underground pipelines on the east side, and residential buildings on the south side. It meets the requirements of surrounding environmental protection.

Through the analysis and summary of the calculation data, it is concluded that the maximum bending moment, shear force, and displacement all occur in the sixth section, which is on the side of the deep foundation pit adjacent to the existing residential buildings. Therefore, it is important to focus on the influence of the existing residential buildings on the stress and displacement of the foundation pit; At the same time, the maximum value of the support and confining pressure plate also occurs at the sixth section, and the third confining pressure value is the highest. The calculation conclusions and data have been applied in engineering, and provide reference and inspiration for the selection of support schemes for super high-rise deep foundation pits in complex environments similar to near subways.

Acknowledgments

This paper is supported by Phased research results of Nantong Science and Technology Plan Project in 2022, “Research on Design and Construction of Deep excavation Support Scheme with “Two Walls Integrated into One and Two-way Support System” Near Subway Commercial Complex”. (Project No. JC22022069, JC12022031, JC2023056) and Phased research results of the school-level project “Research on Mechanical Calculation Method and Influencing Factors of Supporting Structure in Foundation pit” in 2023. (Project No. 23ZK05).

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