Review article

Study on soil reinforcement param in deep foundation pit of marshland metro station

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ABSTRACT

In this paper, the reinforcement method outside the deep foundation pit of a subway station in marshland under a high water level was proposed, and the reinforcement parameters were studied. The influence of reinforcement measures outside the deep foundation pit on deformation and the anti-overturning stability coefficient of the diaphragm wall under high water levels was analyzed. According to the economic law of diminishing marginal returns, the grouting reinforcement parameters were analyzed and optimized. The effects of different reinforcement measures on the safety control of deep foundation pits was analyzed based on field-measured data. The results show that the change in the water level has a significant impact on the stability of the foundation pit, and it is necessary to adopt reinforcement measures for the foundation pit at 10 m below the surface; the change in the reinforcement depth has a more significant impact on the stability of the foundation pit; and the optimized reinforcement parameters can reduce the grouting volume by 45%.

1. Introduction

With large-scale construction of subways in major cities, increasingly deeper foundation pit engineering will be required. The Juzizhou station deep foundation pit of the Changsha Metro Line 2 is located in the Xiangjiang River, which is currently the world's first subway deep foundation pit on an island in a river. The large water level changes and high water levels in the Xiangjiang River and the large excavation depth and small rock socketed depth of the Juzizhou subway station often cause deformation of the retaining structure under high water levels, which greatly reduces the stability of the deep foundation pit structure. To ensure the safety of foundation pit excavation under high water levels, reinforcement measures are needed to strengthen the foundation pit support system. At present, there are many measures to control the stability of the foundation pit [1, 2, 3], but there is no precedent for such projects. In this paper, the method of reinforcement outside the pit is proposed, and the reasonable design parameters of the method are determined.

Many scholars worldwide have researched through theoretical analysis, experiment and numerical calculation the effect of soil reinforcement in and out of foundation pits and the influence of reinforcement designs on the stability of the foundation pits and have accumulated some experience and achievements. In soil reinforcement inside the pit, some scholars [4, 5, 6, 7, 8, 9, 10] mainly studied the influence of reinforcement forms and parameters on the stability of the foundation pit and surrounding structures. Someone optimized the parameters of grouting reinforcement. In the aspect of reinforcement outside the foundation pit, Chengjun Hu and others [11, 12, 13] mainly studied the control effect of reinforcement outside the foundation pit on the stability of the foundation pit through theoretical analysis, field measurement and numerical calculation. According to the existing research results of foundation pit reinforcement, the current research mainly focuses on in-pit reinforcement, and the results are relatively rich, but there is little research on out-of-pit reinforcement. Moreover, due to the lack of subway foundation pits built in marshland in the world, there is little research on the reinforcement of deep foundation pits outside the pit in marshland [14, 15], and there is a lack of theoretical basis for the design and construction of foundation pit reinforcement for subway systems in marshland. Under the conditions of high water levels and low embedding ratios, the effects of reinforcement measures outside deep

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foundation pits on the stability control of foundation pits and the quantitative design of grouting reinforcement parameters need to be studied.

Based on the background of the Juzizhou deep foundation pit project in Changsha City, this paper uses FLAC3D to analyze the influence of reinforcement measures and grouting parameters on the stability of the deep foundation pit and the deformation of the diaphragm wall under the high water level, which provides a reference for the design and construction of similar projects in marshland.

2. Project overview

The Juzizhou subway station is located on an island in the Xiangjiang River and is arranged parallel to the Juzizhou bridge from east to west. The engineering position diagram is shown in Fig. 1.

The Station is an underground four layers and three crosses island type station. The effective length of the platform is 118 m, its width is 12 m, the station total length is 138 m, and the standard width is 22.2 m. The station is constructed by the open-cut and sequential construction method. The depth of the foundation pit is approximately 30.8–31.6 m, and the width is 22.2–25 m. The main enclosure structure of the station is a 1000 mm-thick diaphragm wall and reinforced concrete internal support system with a 6 m-wide reinforcement zone and five vertical supports. The horizontal spacing of the first reinforced concrete support is 8 m, and the cross section is 600 mm × 1000 mm. The horizontal spacings of the second through fifth reinforced concrete supports are 4 m, and the cross sections are 700 × 1200 mm. The design drawings of the retaining structure of the foundation pit are shown in Fig. 2 (see Fig. 3).

The deep foundation pit of the Juzizhou subway station is located in the Xiangjiang River. The eastern and western ends of the station are close to the Xiangjiang River, and the minimum distance from the Xiangjiang River is 13.5 m and 15 m, respectively. There are thick sand layers and gravel layers in the surrounding area, which are highly permeable. The groundwater changes the mechanical properties of the soil, including the cohesion and the internal friction angle, by erosion and increases the deformation capacity of the soil. In particular, the water level in the river increases significantly during the rainy season from July to September each year. According to the relevant recorded information, the maximum water level difference of the Xiangjiang River is up to 10 m, which greatly increases the risk of the instability of the foundation pit. At the same time, the depth of the foundation pit buried in a slate formation is only 6 m, the elastic resistance at the bottom of the foundation pit is small, and the water pressure outside the foundation pit is large, which seriously affects the stability of the deep foundation pit.
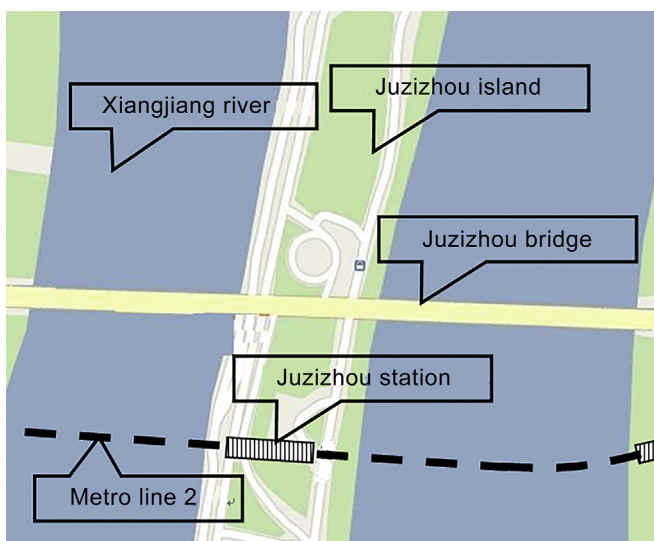

Fig. 1. Juzizhou subway station project location.

Therefore, the stability of the diaphragm wall under high water levels is an important risk point for the deep foundation pit construction. To reduce the impact of river water on foundation pit excavation, reinforcement of the east and west ends of the station must be strengthened. The reinforcement zone in the original plan is that the standard section on the north and south sides has a reinforcement width of 8 m and a depth of 24 m. The expansion section on the east and west sides has a reinforcement width of 9 m and a depth of 31.5 m.

3. Modeling and materials

3.1. The grid model of calculation

The standard section of foundation pit is selected using FLAC3D software to establish a three-dimensional foundation pit model for researching the rock, soil and diaphragm wall using solid element simulation, the purlin, and support using Beam3 element simulation. Because the model, load, and mesh materials are symmetrical, half of the models are built to meet the computational needs. The type of interface is glued, and the contact between different materials adopts the common node setting. From top to bottom, the main strata of the foundation pit are fill (10 m), sandy soil (3 m), gravel (6 m), and fully weathered to slightly weathered argillaceous (sandy) slate (41 m).

The horizontal direction of the foundation pit model extends by approximately 3 times the excavation depth of the foundation pit around the boundary, and the vertical direction extends downward along the boundary by approximately 2 times the excavation depth of the foundation pit. The width of the model is 100 m, and the height is 60 m. The unit size within the depth range is 1 m wide and 1 m high. The size of the unit outside the excavation range becomes 2 m wide and 2 m high.

There are 56,070 meshes. The X-direction and Y-direction of the bottom Z = 0 of the model are fixed constraints. The Y-direction of the left and right sides of the model is constrained. Apply corresponding horizontal constraints on the plane of symmetry according to each formation parameter. The X-direction [16] of the model is constrained before and after the model. The geometric model of the numerical simulation of the foundation pit of the Juzizhou subway station is shown in Fig. 4.

3.2. Simulation of foundation pit excavation

The excavation process is simplified, and the main construction process is extracted to analyze its construction process. The simulation steps of the excavation process are as follows:(see Table 1).

3.3. Calculation parameters

The engineering site of the Juzizhou station belongs to the Xiangjiang terrace. According to geological surveys and borehole exposures, the buried strata at this station are mainly fill, sandy soil, pebble soil, and fully weathered to slightly weathered argillaceous (sandy) slate, and the stress-strain relationship of the soil is approximately that of the Mohr-Coulomb model. The field tests of the soil layers and the reinforcement soil are carried out, and the calculation parameters of the main soil layers and supporting structure are shown in Table 2 (see Table 3).

4. Impact of reinforcement measures outside the pit on the stability of the deep foundation pit

Based on monitoring of the Juzizhou foundation pit, the water level in the foundation pit is mainly 9 m–14 m below the ground level, and the change in the groundwater level is large. The change in the water level has a great influence on the safety of the foundation pit [17]. To ensure the safety of the excavation under the high water level, it is necessary to take reinforcement measures outside the pit to strengthen the foundation pit support system.
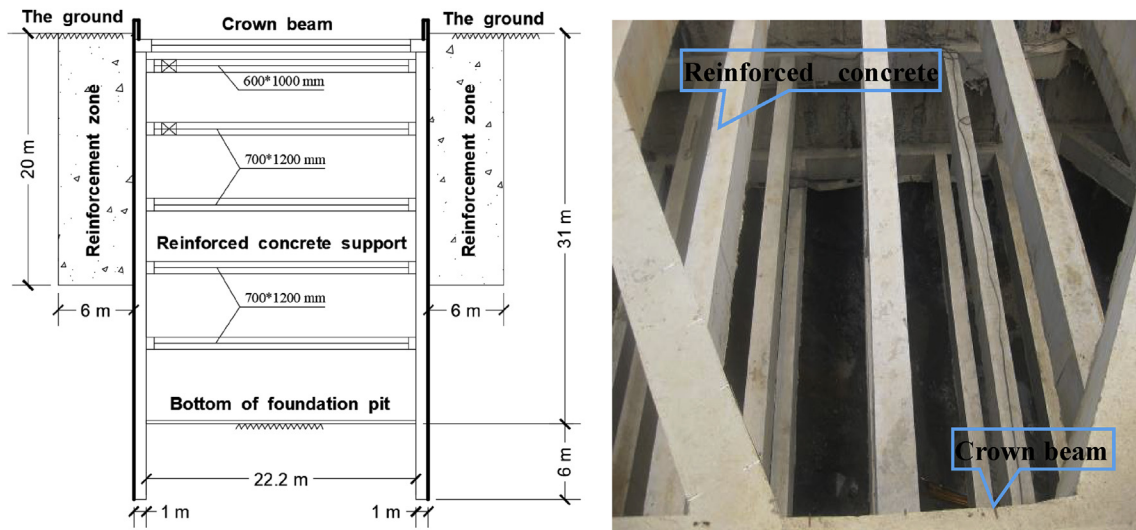
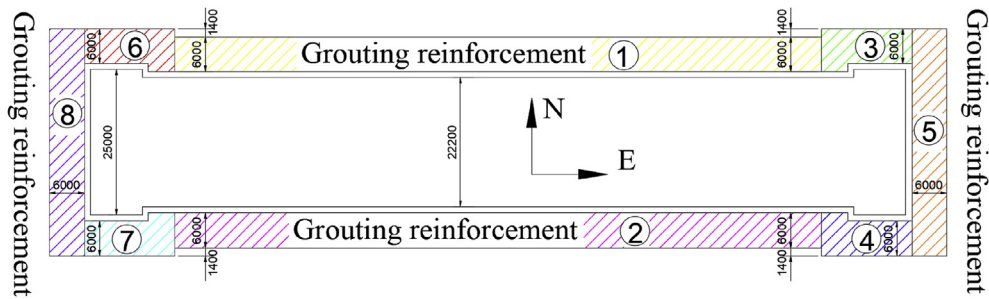Fig. 2. Foundation pit support structure of the Juzizhou subway station.
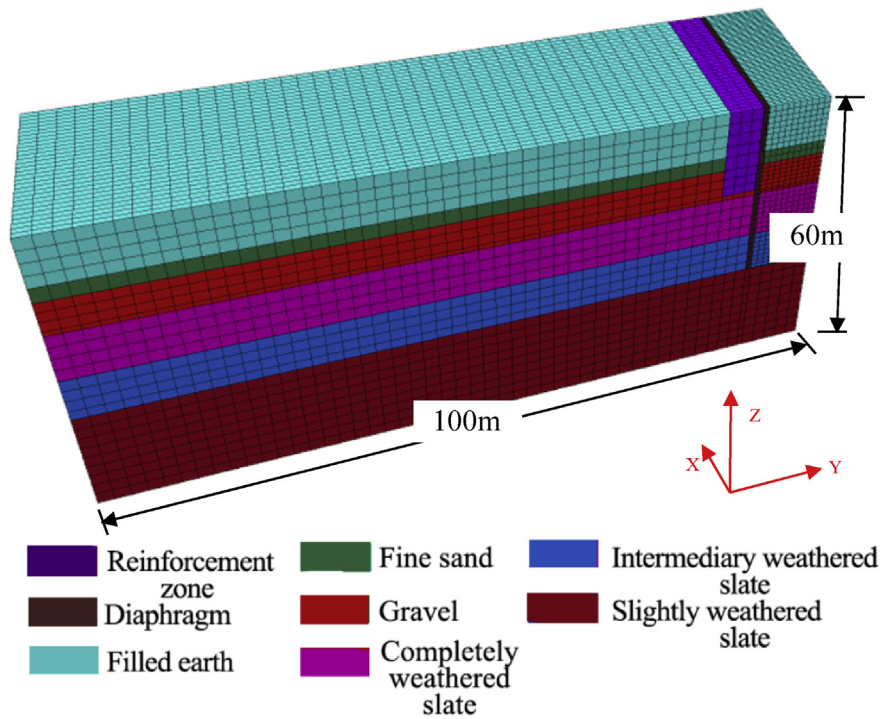

Fig. 3. Juzizhou foundation pit reinforcement plan.

Fig. 4. Geometric model of numerical simulation for Juzizhou station.

Table 1
Simulation of foundation pit construction.

Simulation steps	Simulation content
0	Setting the groundwater level, balancing the initial stress, and constructing the site with walls
1	Excavating the second layer to -3 m, doing the first support, and calculating the balance
2	Excavating the second layer to -8 m, doing the second support, and calculating the balance
3	Excavating the third layer to -14 m, doing the third support, and calculating the balance
4	Excavating the fourth layer to -19 m, doing the fourth support, and calculating the balance
5	Excavating the fifth layer to -25 m, doing the fifth support, and calculating the balance
6	Excavating the sixth layer to -31 m and calculating the balance

Based on the original reinforcement scheme, six kinds of calculation conditions of the height of the water level (6 m, 8 m, 10 m, 12 m, 14 m and 16 m) are set up to study the control effect of the reinforcement measures outside the pit on the stability of the deep foundation pit. The calculated results of the deformation the diaphragm wall and the anti-overturning stability of the foundation pit [16] are shown in Fig. 5 and Fig. 6.

The sixth working condition is selected to analyze the variation in the bending moment of the wall before and after reinforcement, as shown in Fig. 7.

As shown in Fig. 5, Fig. 6 and Fig. 7:

1) The change in the water level of the Juzizhou foundation pit has an obvious effect on the deformation and stability of the foundation pit. When the water level is high, the change in the water level has a great influence on the deformation and stability of the foundation pit. However, when the water level drops to a certain position, the water level will continue to decrease, and the influence of a change in the water level on the stability of the foundation pit is very small. When the water level drops below 14 m, changes in the water level have little effect on the stability of the foundation pit. When the water level is raised from 16 m to the 8 m below the surface, with the reinforcement measures the foundation pit is within the allowable ranges of deformation and stability [18, 19]. In the absence of reinforcement measures, when the water level ranges from 12 m to 10 m below the surface, the influence of the groundwater level changes on the stability is the most obvious. When the water level rises to 10 m below the surface, the foundation pit is already in a dangerous state, and with the rise in the water level, the safety of the foundation pit is continuously reduced. It can be seen that with the increase in the groundwater level, without reinforcement measures the groundwater warning level should be 10 m below the surface, and when the groundwater level is higher than 10 m, the possibility of the instability of the foundation pit is greatly increased. Therefore, the groundwater level that is higher than 10 m below the surface is defined as a high water level. To ensure the stability of the deep foundation pit construction under high water levels, it is necessary to adopt strong measures outside the pit to reduce the influence of the high water levels on the stability of the foundation pit.

2) According to the maximum horizontal displacement of wall deformation, the maximum horizontal displacement of the grouting reinforcement is smaller than that of the nongrouting reinforcement. After the foundation pit excavation, the maximum horizontal displacement of the wall strengthened by grouting is 22.7 mm, the maximum horizontal displacement of the wall not strengthened by grouting is 37.2 mm, and the maximum horizontal displacement of the wall strengthened by grouting decreases by nearly 48%. The maximum bending moment of the wall under grouting reinforcement is 1300 kN m after the foundation pit excavation is completed, and the maximum bending moment of the wall without grouting reinforcement is 1950 kN m. The maximum bending moment of the wall under grouting reinforcement is reduced by 33%. Therefore, the effect of grouting reinforcement on reducing wall deformation and bending moments is very obvious.

3) The maximum displacement of the diaphragm wall under the original reinforcement measures is 22.7 mm, which is much less than the early warning value of the first-grade foundation pit diaphragm wall deformation, indicating that the diaphragm wall deformation has a larger surplus or a higher safety factor. It further shows that the grouting parameters adopted in the original scheme have more room for optimization. To design the reinforcement parameters of the foundation pit more reasonably, it is necessary to add more grouting to the original scheme. Fixed parameters are properly optimized to ensure that the design is economical and safe.

5. Optimization of the reinforcement parameters outside the pit

The above analysis has shown that the soil reinforcement outside the pit is of great significance to the stability of the foundation pit. The feasibility of the design of the original grouting reinforcement scheme is considered to further study the influence of the reinforcement on the stability of the foundation pit to optimize the reinforcement parameters. Based on the above simulation model and the original reinforcement scheme, first, the influence of the reinforcement zone width (width of 2 m, 4 m, 6 m, 8 m and 10 m) on the stability of the foundation pit is studied in the case of the original reinforcement depth. Based on the economic law of diminishing marginal returns [20, 21, 22], combined with safety, the grouting reinforcement width is optimized to obtain a reasonable value. Then, the influence of the reinforcement depth (depth

Table 3
Main physical parameters of the supporting structure.

Project name	P (kg/m³)	Section h×w (m)	Es (Mpa)	Poisson's ratio	Horizontal spacing support
Diaphragm wall	2500	37×1	30e3	0.2	
First concrete support	2500	1.0×0.6	30e3	0.2	8 m
Second to fifth concrete supports	2500	1.2×0.7	30e3	0.2	4 m

Table 2
Main physical and mechanical indexes of the soils.

| Geotechnical names	Thickness	P (kg/m³)	Es (MPa)	C (kPa)	Φ (°)	Void ratio	K_0	Poisson's ratio
Filled earth	10 m	1940	7.50e6	15	20	0.829	0.45	0.30
Fine sand	3 m	2000	2.08e7	50	24	0.655	0.36	0.30
Gravel	6m	2030	2.27e7	0	35.0	0.877	0.33	0.28
Completely weathered slate	11 m	2700	7.58e7	800	43	0.12	0.30	0.28
Intermediately weathered slate	9 m	2720	1.79e8	1000	55	0.03	0.28	0.22
Slightly weathered slate	21 m	2760	4.76e8	2500	45/65	0.01	0.26	0.22
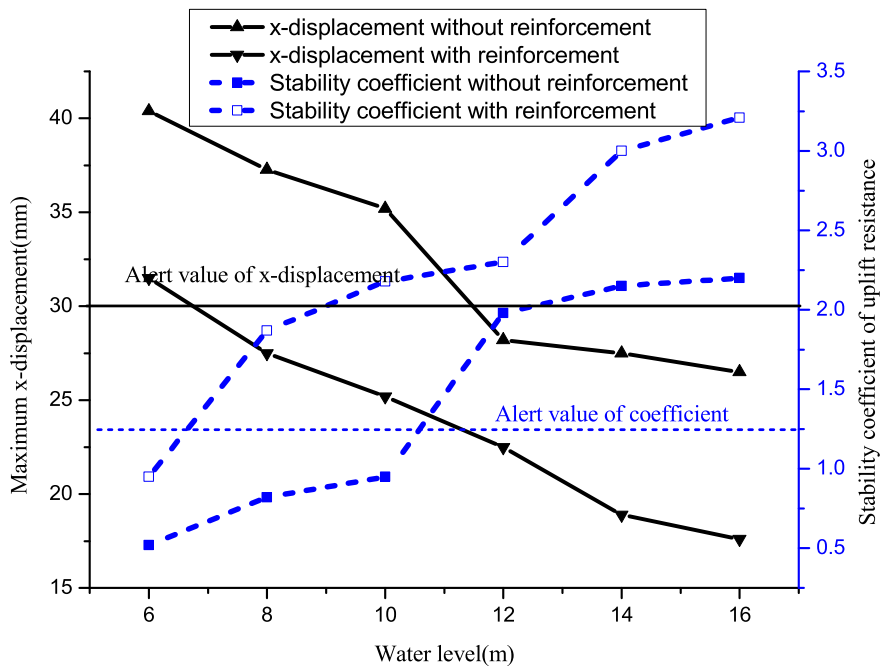
Fig. 5. Influence of water level variation on the deformation and stability of the foundation pit with or without reinforcement.
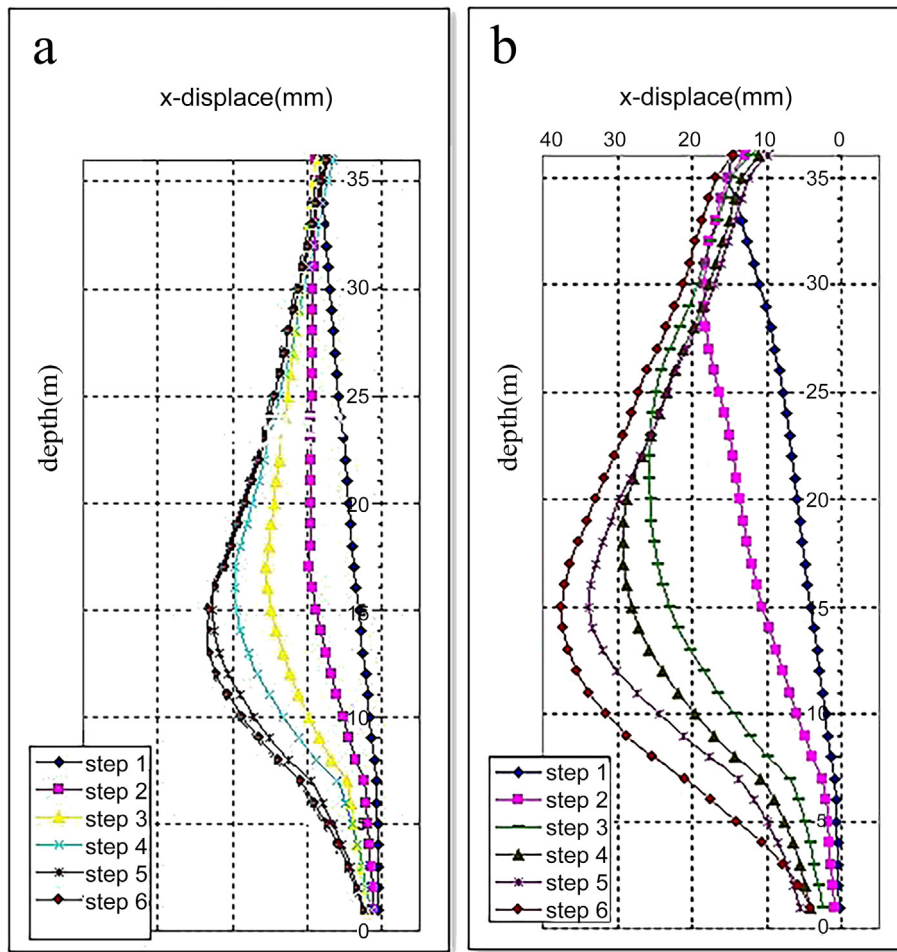

Fig. 6. Influence of reinforcement measures on the horizontal displacement of the wall under high water. (a) With reinforcement, (b) Without reinforcement.
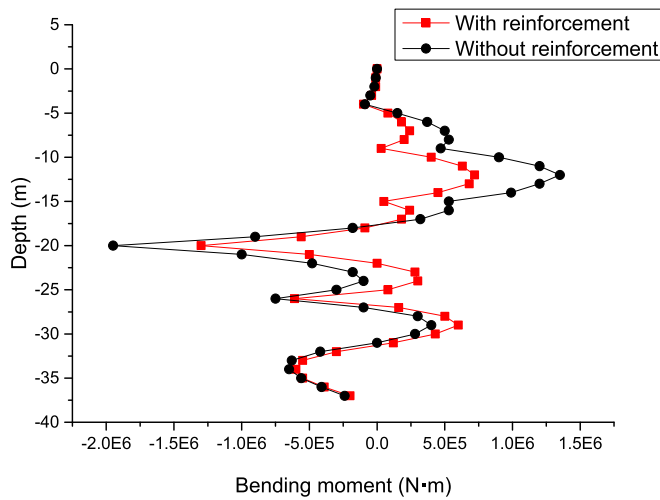
Fig. 7. Influence of reinforcement measures on the bending moment of the wall under high water.

of 12.5 m, 15 m, 17.5 m, 20 m, 22.5 m and 25 m) on the deformation stability of the foundation pit is discussed, and the depth of grouting reinforcement is optimized from economic and safety considerations.

5.1. The impact of the width of the reinforcement outside the pit

Analysis of Fig. 8 shows the following:

(1) The maximum horizontal displacement of the diaphragm wall decreases as the reinforcement width increases. After the foundation pit excavation is completed, the maximum horizontal displacement of the diaphragm wall is 35.3 mm, 34.48 mm, 29.76 mm, 27.7 mm and 27.0 mm at reinforcement widths of 2 m, 4 m, 6 m, 8 m, and 10 m, respectively. When the reinforcement width ranges from 4 m to 6 m, the horizontal displacement of the wall decreases obviously. When the reinforcement width is 4 m, the displacement value of the wall is 34.48 mm, which is more than

30 mm [19]. As the reinforcement width continues to increase, the maximum horizontal displacement of the wall gradually decreases from 6 m to 8 m. Considering the effect of the reinforcement width on the deformation of the ground wall, the reinforcement width of 6 m is the reinforcement "limit value".

(2) The anti-overturning stability coefficient of the foundation pit increases with increasing reinforcement width. When the width value is small, the reinforcement width has a significant effect on the stability coefficient. When the width is more than 6 m, as the reinforcement width continues to increase, the stability coefficient gradually increases. When the width value is 4 m, the stability factor is 0.76, which is less than the minimum pit stability requirement at a safety factor of 1.25. As the reinforcement width continues to increase from 4 m to 6 m, the increase in the stability factor is the largest. When the width value is 6 m, the stability factor is 2.4 meeting the stability requirements of a foundation pit safety factor of 1.25 [18]. Considering the effect of the reinforcement width on the stability of the foundation pit, there is a limit value of the reinforcement width, and the reinforcement width of 6 m is the reinforcement "limit value".

In view of the controlling effect of the reinforcement width on the deformation and stability of the foundation pit, there is a limit; when the reinforcement width is more than the limit, continuing to increase the reinforcement width plays a small role in the controlling effect, which follows the economic law of diminishing marginal returns. Based on the law of diminishing marginal returns and considering the safety requirements of the deep foundation pit construction under high water levels, the reasonable reinforcement width is 6 m. Increasing the scope of the reinforcement not only has little impact on the wall deformation but also increases the cost of the project.

5.2. The impact of the depth of the reinforcement outside the pit

Fig. 9 shows the following:

(1) The maximum horizontal displacement of the diaphragm wall decreases with increasing depth of reinforcement; however, after
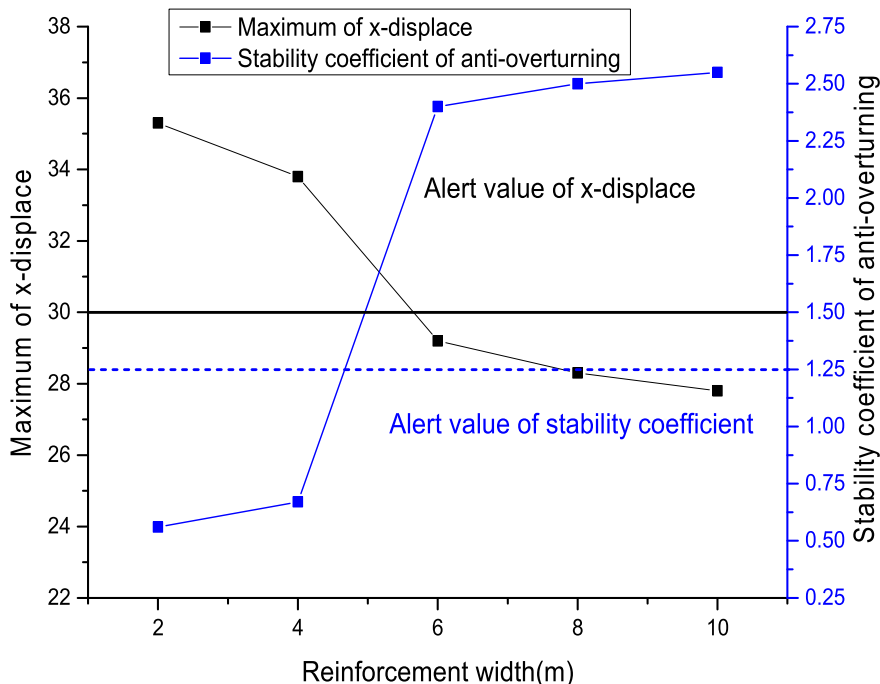

Fig. 8. Influence of the reinforcement width on the deformation and stability of the foundation pit.
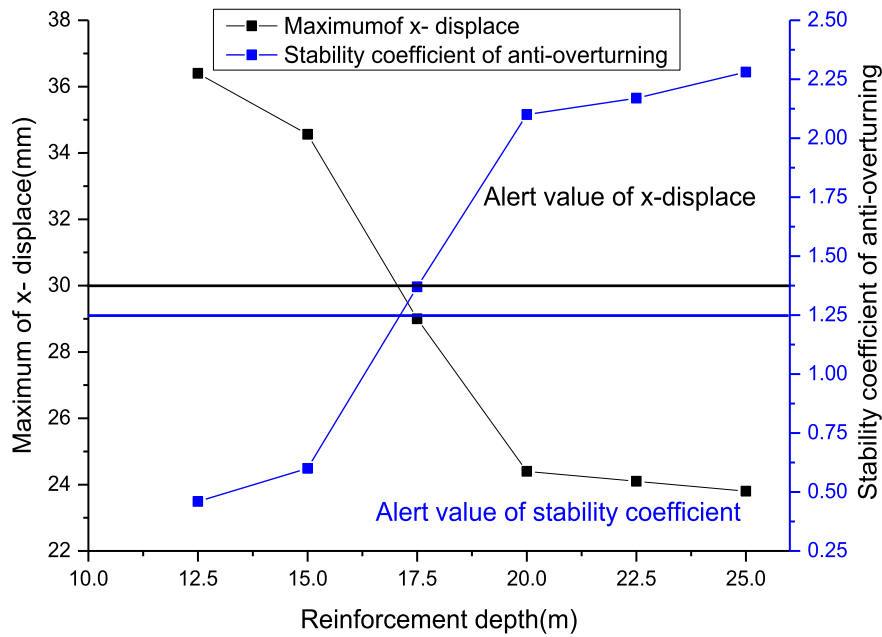
Fig. 9. Influence of reinforcement depth on the deformation and stability of the foundation pit.

the reinforcement increases to a certain depth, the trend of decreasing displacement lessens. When the depth of reinforcement increases from 12.5 m to 15 m, the maximum horizontal displacement of the wall is reduced by 5%; when the depth of the reinforcement is increased from 15 m to 20 m, the maximum horizontal displacement of the diaphragm wall is reduced by 29%, which is very significant. When the depth of reinforcement

increases from 20 m to 25 m, changes in the maximum horizontal displacement of the wall are very small. The main reason is that when the reinforcement depth is less than 20 m, the reinforcement area is mainly in the soft soil layer. With the excavation of the foundation pit, the internal and external soil and water pressure increase, and the wall deformation increases, thus weakening the reinforcement effect. When the reinforcement depth is increased
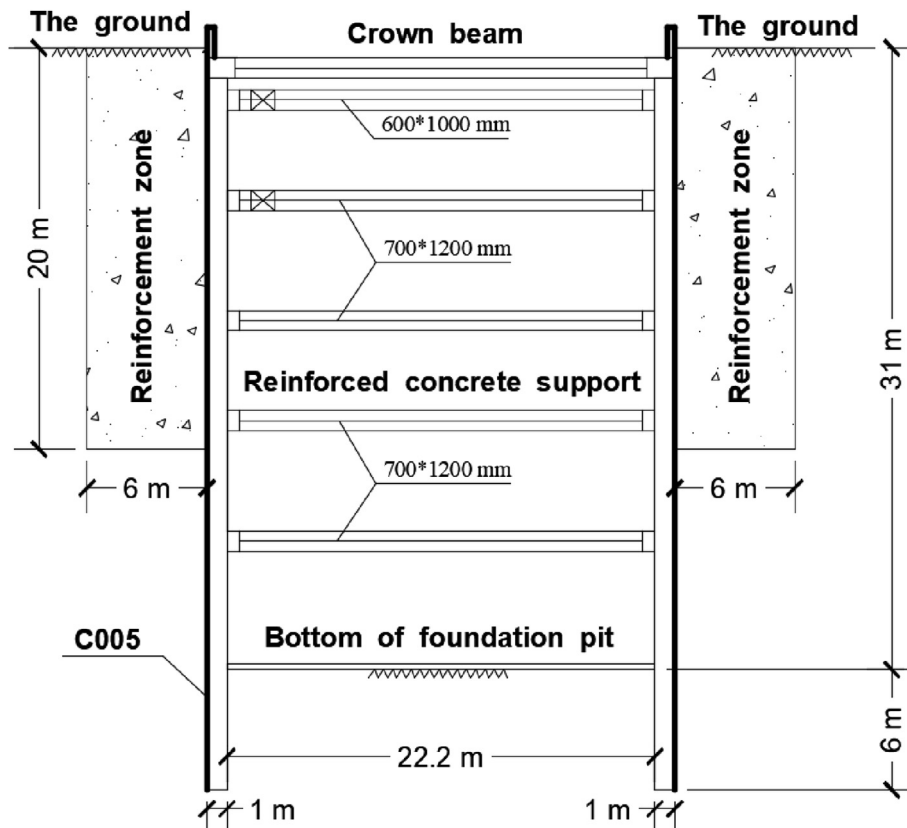

Fig. 10. Typical reinforcement.

Fig. 11. Diaphragm wall horizontal displacement monitoring point C003.

Table 4
Comparison of the effects of the optimized reinforcement scheme.

Reinforcement scheme	Diaphragm wall displacement (mm)	Grouting volume (m³)
Original scheme	22.7	41730
Optimized scheme	24.85	23180

to 20 m, the reinforcement area enters the slate from the soft soil layer, and the reinforcement area and the slab layer are connected together, which greatly improves the deformation resistance of the wall. When the reinforcement depth is between 10 m and 15 m, the maximum horizontal displacement of the wall is more than the wall warning value of 30 mm. When the reinforcement depth increases to 17.5 m, the maximum horizontal displacement of the diaphragm wall is reduced to 28.2 mm, which satisfies the limits of the horizontal displacement of the wall. Considering the effect of the reinforcement depth on the deformation of the foundation pit, the reinforcement depth has a limit value, and the reinforcement depth of 20 m is the reinforcement "ultimate depth". Considering the effect of the reinforcement depth on the deformation of the diaphragm wall, the reasonable depth of reinforcement is 17.5 m–20 m.

(2) The anti-overturning stability coefficient of the foundation pit increases with increasing reinforcement depth. When the depth is less than 20 m, the effect of the reinforcement depth on the stability coefficient is significant; when the depth is more than 20 m, with increasing reinforcement depth, the increases in the stability coefficient gradually become smaller. With the strengthening depth increasing from 15 m to 20 m, the stability factor increases significantly. When the reinforcement depth is 15 m, the stability factor is 0.61, which does not meet the foundation pit stability safety factor of 1.25. When the reinforcement depth is 17.5 m, the stability factor is 1.37, which meets the stability requirements of a foundation pit safety factor of 1.25; when the reinforcement depth is more than 20 m, increasing the depth of reinforcement to control the stability of the pit is of little significance. Considering the effect of the reinforcement depth on the stability of the

foundation pit, the reinforcement depth has a limit value, and the reinforcement depth of 17.5 m–20 m is the reinforcement "ultimate depth". Based on the above analysis, the effect of the reinforcement depth on the deformation and stability of the foundation pit is in accordance with the influence of the reinforcement width. Based on the economic law of diminishing marginal returns, considering the safety requirements of deep foundation pit construction under high water levels, when the grouting reinforcement does not enter the slate layer, the reinforcement depth is stronger than that of the ground wall and the stability coefficient of the foundation pit. After the reinforcement area enters the slate layer, the effect of the reinforcement depth on the stability of the foundation pit is not obvious. The reasonable reinforcement depth of the pit is in the range of 17.5 m–20 m.

(3) Comparing the influence of the reinforcement width on the deformation of the connected diaphragm wall, when the width of the reinforcing increases from 2 m to 6 m (limit value), the maximum horizontal displacement of the diaphragm wall decreases from 35.3 mm to 29.76 mm, and the amplitude is reduced by 15.1%. That is, for each additional 1 m reinforcement width, the displacement is reduced by 3.77%. When the depth of reinforcement increases from 12.5 m to 20 m (ultimate depth), the maximum horizontal displacement of the wall is reduced from 36.69 mm to 24.5 mm, and the amplitude is reduced by 31.81%. That is, for each additional 1 m of reinforcement depth, the displacement is reduced by 4.56%. Increasing the depth of reinforcement to control the pit deformation is much better than increasing the width of reinforcement. Under the conditions of the site regulations and the capacity of the mechanical equipment, the actual engineering grouting design should control the grouting reinforcement depth and control the reinforcement width as the supplement.

6. Analysis of the safety control effect on site construction

To reduce the influence of the Xiangjiang River on foundation pit excavation, the optimized reinforcement parameters are applied to the foundation pit reinforcement of the Juzizhou station. The width and depth of the diaphragm wall around the foundation pit are 6 m and 20 m, respectively. The typical reinforcement section is shown in Fig. 10.(see Fig. 11)

According to the actual situation of the foundation pit, there are 14 inclinometer tubes around the foundation pit, of which 8 monitoring points can normally be tested. To avoid repetitive analysis, this paper takes the standard section in the middle of the foundation pit as the research object, while the damage at points C004 and C005 in the middle
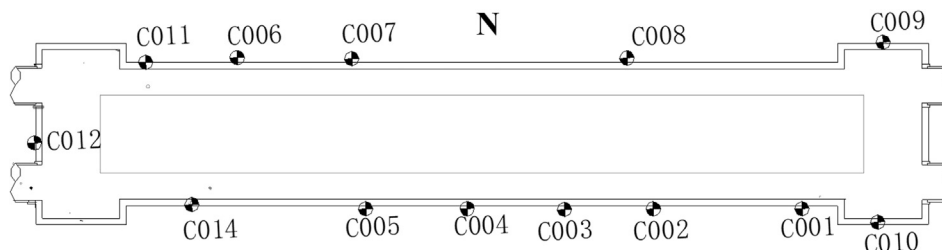

Fig. 12. Layout diagram of the horizontal displacement monitoring points of the diaphragm wall.
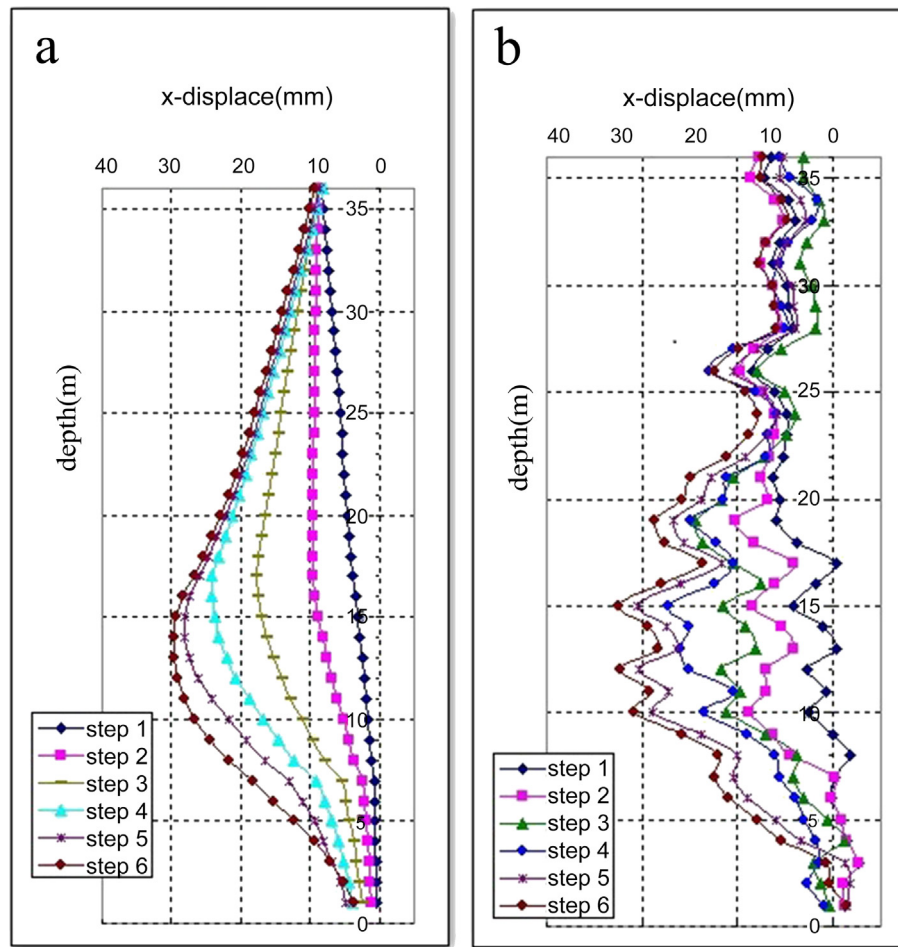
Fig. 13. Comparison and analysis of the reinforcement simulation and site-measurement results. (a) Simulation results, (b) Site-measurement results.

of the foundation pit cannot normally be tested during construction, so the inclinometer C003 near the section is selected to proceed. Deformation characteristics of the row diaphragm wall are analyzed. The arrangement of the inclinometer tube is shown in Fig. 12.

According to the engineering design requirements, the slurry filling rate should be more than 70%. Combined with the pit size and grouting design geometric parameters, the grouting amount is calculated before and after the optimization of the reinforcement, which is shown in Table 4. The calculated values and measured values of the maximum horizontal displacement of the diaphragm wall under the optimized reinforcement measures are shown in Fig. 13.

Table 4 indicates that the grouting amount of the original reinforcement scheme is 41730 m3, and the optimized grouting design needs 23180 m^3. Compared with the original grouting reinforcement scheme, the optimized grouting reinforcement scheme can reduce the grouting amount by 45%. It can be seen that the optimized grouting reinforcement design can save a significant amount of grouting material and grouting costs.

Fig. 13 and Table 4 also indicate that after the excavation of the foundation pit, the maximum horizontal displacement of measuring point C003 on the diaphragm wall is 24.85 mm, which is less than the warning value of 30 mm, and the diaphragm wall is in a safe and stable state. The maximum horizontal displacement of the diaphragm wall caused by the excavation under the original reinforcement scheme is 22.7 mm. The horizontal displacement of the diaphragm wall with the optimized reinforcement scheme is 9.5% higher than that of the original scheme, but the displacement control is within the range of the warning value. The grouting reinforcement measures can meet the safety factor requirement of the foundation pit construction of the Juzizhou subway

station under high water levels.

As shown in Fig. 13, considering the deformation mode of the diaphragm wall at different stages of excavation, the results of the numerical simulation are basically consistent with the measured results. From the numerical results, the measured maximum horizontal displacement is 24.85 mm, but the maximum horizontal displacement calculated is 29.5 mm. The horizontal displacement values in the simulation are slightly larger than the measured values. The relative error between the measured results and the calculated results is less than 20%. From the engineering point of view, the relative error is also within the allowable range, so that the simulation results and experimental results are consistent, which illustrates the validity of the calculation model.

7. Conclusions

(1) Water level changes outside the Juzizhou subway station have a significant impact on the stability of the foundation pit. The warning water level of the deep foundation pit without reinforcement is 10 m below the ground surface. There is a great risk in the foundation pit construction exceeding the warning water level. It is necessary to adopt soil-reinforcement measures outside the pit to strengthen the support system.

(2) There are reasonable limits for the width and depth of the soil reinforcement. For the Juzizhou station pit, the reasonable value of the width is 6 m, and the depth is 17.5 m–20 m. The change in the reinforcement depth of the pit has a greater influence on the stability of the foundation pit than the change in reinforcement width. The engineering grouting design should first control the

grouting reinforcement depth and then control the reinforcement width as the supplement.

(3) The optimized grouting parameters, which can meet the safety factor requirement for the construction of the foundation pit under high water levels, are applied in the reinforcement of the Juzizhou subway station pit, and the grout injection volume can be reduced by 45% compared with the original grouting design.

Declarations

Author contribution statement

Wei Wang: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Zhao Han: Analyzed and interpreted the data; Wrote the paper.

Jun Deng: Conceived and designed the experiments; Performed the experiments.

Xinyuan Zhang & Yanfei Zhang:Performed the experiments; Contributed reagents, materials, analysis tools or data.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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