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Key Technologies for Construction Control of Large Double Sinking Wells in Urban Core Areas in Complex Environments

Zhicheng Bai[a], Yun Gao[b], and Bing Yang[c]

China Construction Fourth Engineering Bureau Sixth Construction Co., Ltd, Shanghai 201199, China

[a]463803941@qq.com, [b]2014286859@qq.com, [c]805107374@qq.com

Abstract

At present, there is relatively little theoretical research on the design and construction of open caisson projects in special site environments, especially for the adjacent double open caisson projects in the core areas of coastal cities along the river. This article conducts theoretical research on the construction of double sunk wells in the urban core area under complex geological conditions and proposes corresponding construction technical measures. It has accumulated engineering experience under similar engineering conditions and has certain engineering application significance. The research results indicate that double sinking wells should be constructed symmetrically as much as possible. During the secondary elevation stage of the shaft wall, the stability of the elevation should be checked and calculated. The stability of the anti uplift at the bottom of the sinking well and the sinking coefficient of the sinking well should be analyzed in advance. On this basis, necessary measures such as precipitation, soil removal construction, sinking assistance, and deviation correction control should be taken if necessary.

Keywords

Urban Core Area; Up Close; Double Sinking Well; Construction.

1. Introduction

The design and construction theory and construction technology of open caissons have made significant progress [1-2], and there is relatively little research on open caissons [3-4]. However, there is relatively little research on the design and construction theory of open caissons in special site environments [5-6], especially for the adjacent double open caissons along the river and seaside, and there is very little research and engineering experience. This article conducts theoretical research on the construction of double sunk wells in the urban core area under complex geological conditions and proposes corresponding construction technical measures. It has accumulated engineering experience under similar engineering conditions and has certain engineering application significance.

The two caissons studied in the background engineering are relatively close in distance and are circular and rectangular. The impact of double caissons sinking on the soil and between the caissons cannot be ignored, and the sinking is not easy to stabilize. On the other hand, the soil engineering properties of the proposed site are complex and variable, with a high groundwater level and many unknown factors overall; Moreover, the safety distance between adjacent wells is relatively small, resulting in higher risks. In addition, the project is located in the core area of the city and has extremely strict control over the surrounding environment. Compared to common open caissons, these types of open caissons require higher and more precise construction techniques. Therefore, studying and

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analyzing the construction process and control technology of deep and large caissons in complex environments, and accumulating experience in deep and large caisson construction, is of great value.

2. Secondary Elevation Analysis

2.1 Overview of Caisson Heightening Production

There are two sunken wells in this project, namely rainwater pump rooms (size: 30.6m × 28.3m, sinking depth 14.03m), inlet gate shaft (diameter 9.8m, sinking depth 12.56m), with a spacing of about 13m between the two sinking shafts. In this project, the sinking well adopts a construction plan of three times production and two times sinking. The first production length of the inlet gate shaft was 3.55 meters, the second production length was 7.21 meters, and the third production length was 2 meters. The first production length of the rainwater pump station is 5 meters, the second production length is 7.43 meters, and the third production length is 1.8 meters.

2.2 Connected to High Stability Factor of Safety Calculation.

Before the construction of caisson reinforcement, stability checks should be conducted to avoid instability of the caisson. The stability coefficient can be calculated using the following formula.

$$k_c = \frac{G_k}{T_f + R_1 + R_2 + F_t} \tag{1}$$

In the equation: G_k --Standard value of self weight of open caisson (kN);

F_t --The buoyancy of groundwater stops precipitation after the first sinking;

T_f --The total frictional resistance between the side wall and the soil;

R_1 --The ultimate bearing capacity of the soil under the foot surface and inclined surface of the sunken well blade;

R_2 --The ultimate bearing capacity of the soil under the bottom beam.

The lateral resistance T_f of the sunken well sidewall and the surrounding soil layer can be calculated using the following formula:

$$T_f = \pi \times D \times A \tag{2}$$

Among them: D --Outer diameter of the caisson (m);

A --The frictional resistance per unit circumference (kN/m), considering the presence of external steps in the caisson, can be calculated using the following formula:

$$A = (H - 2.5) \times f \tag{3}$$

f --Standard value of frictional resistance (kN/m).

H --The sinking depth of the sinking well (m).

After calculation, k_c =1.06,Unable to meet the requirements for elevation. Generally speaking, the stability coefficient k_c of the raised caisson should be controlled between 0.8 and 0.9.

2.3 Connect to High Stability Control Measures

It is difficult to meet the stability requirements for the secondary connection of the sinking well, and stability control measures must be considered. According to the formula for calculating the stability coefficient of the connection, if the value needs to be reduced, two main measures can be taken: firstly, to reduce the weight of the sinking of the sinking well in stages, that is, to reduce the height of the sinking well in stages and sink multiple times; Secondly, increasing the sinking resistance of the caisson can be further divided into increasing the frictional resistance of the shaft wall, increasing the ultimate bearing capacity of the soil under the blade foot and bottom beam, and increasing the buoyancy of groundwater on the caisson.

The method of reducing the self weight of caisson sinking in stages will increase the number of caisson sinking times and extend the construction period, which is not allowed in terms of construction period and cost. Therefore, the method of increasing the frictional resistance between the shaft wall and the soil is considered to control the settlement stability coefficient. Specifically, by backfilling the soil in stages into the shaft, the frictional resistance between the inner wall and the soil is increased, and the pressure on the bottom beam is formed.

Overall, after the first sinking of the open caisson, the precipitation will be stopped and 1m thick medium coarse sand and 1m thick clay will be backfilled in layers inside the well. The backfill will be compacted in layers.

3. Analysis of Sinking Coefficient of Open Caisson

To ensure the smooth and safe sinking of the caisson, the sinking coefficient of the caisson should be calculated based on the height of the caisson section, the sinking in stages, and the specific situation of the sinking through each soil layer.

3.1 Calculation of Frictional Resistance between Soil Layer And Wellbore

During the sinking stage of the caisson, the total lateral resistance provided by the soil layer on the outer side of the sidewall can be calculated using the following formula:

$$T_f = UA \tag{4}$$

In the equation, U --Peripheral perimeter of the side wall of the caisson (m).

A --The frictional resistance per unit circumference (kN/m) can be calculated using the following formula:

$$A = (H - 2.5) \times f \tag{5}$$

f --Standard value of frictional resistance between shaft wall and soil (kPa).

H --The sinking depth of the sinking well (m).

If drag reduction measures are to be taken during the construction phase, the frictional resistance A per unit circumference should be calculated using the following formula:

$$A = \left[\frac{1}{2}(H + h_1 - 2.5) \right] f \tag{6}$$

Among them: h_1 Indicates the height of the step at the bottom of the sidewall, which is the starting position of corresponding drag reduction and sedimentation assistance measures (such as mud and air curtains).

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3.2 Calculation of Settlement Coefficient

According to the Technical Specification for Construction of Open Caisson and Pneumatic Caisson, the sinking coefficient can be calculated using the following formula:

$$k_{st} = \frac{G_k - F_t}{T_f + R_1 + R_2} \tag{7}$$

In the equation: k_{st} --Sinking coefficient;

G_k --Standard value of self weight of open caisson (kN);

F_t --Groundwater buoyancy (kN), taken as 0 during drainage sinking.

When the caisson sinks to silt or silty clay, the soil removal method of digging the bottom beam and not digging the bottom beam is adopted. The sinking coefficient of the caisson can be maintained between 1.03 and 1.48. By reasonably controlling the excavation range of soil removal, the requirements of the specification for sinking coefficient can be met. Furthermore, when the caisson enters the lower silty clay, the physical and mechanical properties of the soil are good, and its stiffness and frictional resistance are both relatively high; Even if the bottom beam of the caisson is excavated, the sinking coefficient of the caisson remains between 0.89 and 0.93. However, if the bottom beam is excavated, this coefficient is smaller and cannot meet the requirements of the specifications. Therefore, when the edge of the sunken well gradually enters the silty clay, it will be difficult for the lower part of the sunken well to sink, and drag reduction measures should be taken in advance.

4. Stability Analysis of Anti Uplift at the Bottom of the Well

The open caisson of this project adopts drainage sinking. Due to the large sinking depth of the open caisson, the stability of anti heave at the bottom of the well is considered to be analyzed. When the open caisson sinks in the soil layer, the safety factor value of anti heave at the bottom of the well can be checked and calculated according to the Underground Engineering Design and Construction Manual. Based on the above calculation, the open caisson of this project adopts drainage sinking, and its bottom anti uplift stability meets the requirements.

5. Construction Control Technology for Sinking of Open Caisson

5.1 Key Construction Techniques

As shown in Figure 1, the two adjacent wells in this project are 13 meters apart, and the overall size of the sunk wells is large, making it difficult to maintain stability during the sinking stage and the sinking impact range is wide. In order to avoid posture interference between the two wells, cement soil mixing pile construction is hereby carried out within the two sinking ranges. Construction of enclosure structure for rainwater pump station, in the form of three-axis mixing pile, with a size of Ø 850@600 The depth is 14.23 meters, and the quantity is 228 pieces. Construction of the enclosure structure for the inlet gate well, in the form of a two axis cement mixing pile, with a size of Ø 700@500 The depth is 10.5 meters and the quantity is 63 pieces. The bottom of the inlet gate well and rainwater pump room pit shall be compacted with grouting, with a thickness of 3m. The compaction grouting range shall be 2m outward from the outside of the open caisson. The grouting material is a pure cement suspension mixed evenly with ordinary Portland cement with a strength grade of 42.5, and mixed with 2.0% water glass accelerator. Grouting hole spacing: 1.0m, arranged in a plum blossom shape. The curing agent for the mixing pile of the rainwater pump station is 42.5 ordinary Portland cement, with a cement content of about 20% in the pile body. The specific content is determined based on the pile forming process and pile testing. Ordinary Portland cement with

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strength grade of 42.5, cement mixing ratio of 15% and Water–cement ratio of 1.5 is used for the two shaft mixing pile of the intake gate shaft.

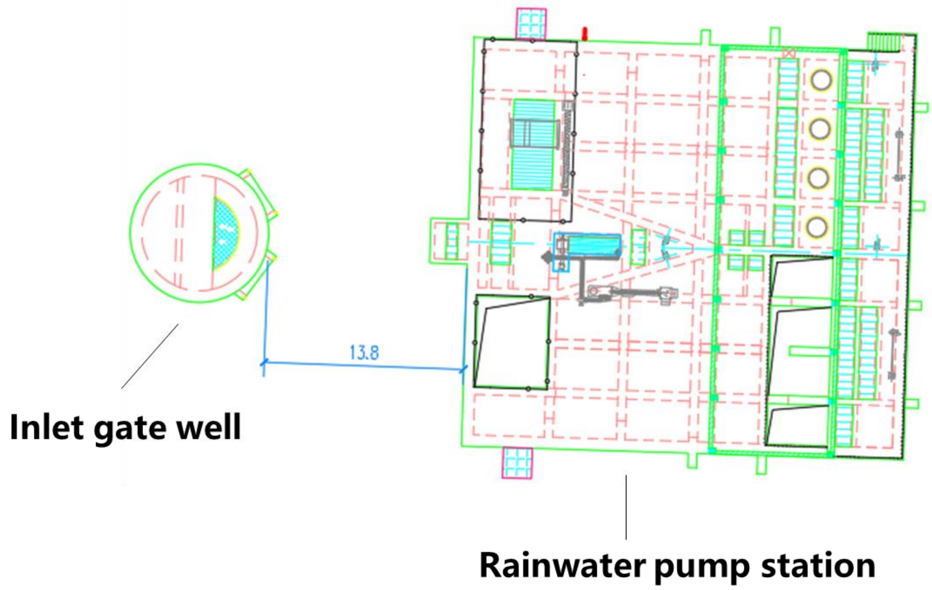

Figure 1. Double sinking well diagram

In this project, in order to reduce the mutual influence of sinking of open caissons, the first step is to choose a synchronous sinking plan with less mutual interference in the selection of construction plans. In the actual construction stage, sufficient equipment and personnel should be equipped to ensure that the two wells are in a synchronous sinking state as much as possible. On the other hand, during the production stage of the two well walls, embedded parts are selected to be installed at heights of approximately 4m, 8m, and 12m above the ground; If there is a significant deviation in the attitude of the sunken well during the sinking stage, this embedded part can be used as a connection point to install a steel support to maintain a stable attitude of the sunken well. Finally, during the actual construction phase, soil can also be piled up on the side of the inclined shaft wall to form support and reduce the deviation.

In order to achieve the stability requirement of secondary elevation, after the first sinking of the caisson, measures of backfilling inside the well are taken to increase the support reaction force of the soil on the caisson wall and reduce the stability coefficient of elevation. The backfilling in the well mainly involves backfilling with sand and cohesive soil, with 1m of coarse sand first and then 1m of cohesive soil; The backfill soil layer is about 1m high, and the next layer is backfilled after one layer is compacted.

In this project, the first sinking depth of the caisson is relatively small, and the posture can be effectively controlled. When the sinking well is completed and the second sinking begins, its posture during the sinking phase is difficult to control. To ensure the smooth and stable sinking of the caisson, through calculation and combined with construction experience, it is recommended to maintain the central bottom of the excavated well as much as possible from the second sinking to a depth of 12m, without arbitrarily removing the bottom beam and soil under the edge, in order to maintain a stable posture of the caisson.

At the same time, the sunken well wall is in an outer stepped shape. During the initial sinking stage of the sunken well, when there is a gap between the well wall and the surrounding soil, medium coarse sand should be used to backfill it, so that the stress on the well wall is uniform to reduce the change in the posture of the well wall. In the actual construction stage, strengthen the monitoring frequency and guide the construction with actual data; If the sinking well deviates, the excavation area inside the well can be adjusted based on the monitoring results of soil pressure and frictional resistance, or sinking assistance measures can be taken as needed.

Due to the long construction time of secondary elevation and the consolidation effect of soil, the disturbance of the soil around the well caused by the first sinking gradually recovers, and the frictional resistance will also gradually increase. However, the theoretical sinking coefficient is relatively large during secondary sinking excavation. Under this condition, in order to ensure the smooth sinking of the caisson, the excavation area should be reasonably determined based on monitoring data, and the soil should be excavated evenly and symmetrically from the well. Do not exceed the bottom of the pot, which may cause sudden sinking and cause significant deviation in the attitude of the caisson.

When entering soil with relatively poor engineering properties, it is beneficial for the sinking of the caisson, but it does not meet the requirements for anti uplift in the well, especially when the edge of the caisson enters the silty clay, the complete coefficient of anti uplift is smaller. In response to this characteristic, during the sinking stage of the caisson, the excavation area should be reasonably controlled, symmetrical and balanced construction should be carried out, and a certain amount of soil should be retained near the blade foot and bottom beam. When the edge of the sinking well enters the underground soil layer ⑤, due to the good engineering properties of the soil, the anti uplift at the bottom of the well meets the requirements, but the sinking coefficient is relatively small; For this, the excavation range can be appropriately expanded or the soil at the bottom of the bottom beam or blade foot can be partially excavated according to the actual situation to reduce the soil pressure at the bottom beam and blade foot, so as to ensure the smooth sinking of the caisson.

5.2 Measures for Reducing Resistance During the Sinking Stage of Open Caisson

From the calculation results of the sinking coefficient of the caisson mentioned above, it can be seen that before entering the ⑤ layer of soil, the poor engineering properties of the soil are conducive to the sinking of the caisson, and the sinking coefficient meets the sinking requirements without the need to reduce resistance. When the edge of the sinking well gradually enters the soil layer ⑤, due to the good engineering properties of the soil layer, it is not conducive to sinking. Under the theoretical calculation of the sinking coefficient, the resistance can be reduced in real time based on the soil removal situation in the well.

In terms of drag reduction measures, the first step is to pre lay grouting pipes and air curtain pipes during the wellbore construction phase. If drag reduction is required during the sinking phase, the thixotropic drag reduction mud or compressed air can be injected into the grouting and air curtain pipelines to assist in the sinking of the sinking well. Secondly, during the actual sinking stage of the caisson, a trench with a width of about 300mm and a depth of about 500mm should be excavated along the outer wall of the caisson in advance, and thixotropic mud should be injected to further reduce soil friction and prevent surrounding soil collapse, ensuring the smooth sinking of the caisson.

Due to the fact that dewatering construction has already been carried out around the sunken well during the sinking stage, if thixotropic mud is used to assist in sinking and reduce drag during the excavation stage, it is very easy to cause thixotropic mud leakage around the wellbore due to the pressure difference inside and outside the wellbore, reducing the drag reduction effect. Therefore, compressed air, i.e. air curtain, is mainly used to reduce drag.

6. Conclusion

A theoretical analysis method was used to study the key technologies for the construction of adjacent double caissons in the core area of coastal cities in the Yangtze River. The main conclusions are as follows:

(1) Double sinking wells should be constructed symmetrically as much as possible, and during the secondary elevation stage of the shaft wall for ultra deep sinking wells, the stability of the elevation should be checked and calculated.

(2) An analysis of the stability against uplift at the bottom of the caisson and the sinking coefficient of the caisson should be conducted in advance.

(3) Based on the analysis of the results, comprehensive measures such as precipitation, soil removal construction, settlement assistance, and deviation correction control can be adopted to reduce the impact of sinking well construction on the surrounding environment.

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