

Research on Prefabricated Open Caisson Construction Technology

Chaoyang Li*

China First Metallurgical Group Co. Ltd., Wuhan 430081, China

*Corresponding author: Chaoyang Li, 86755593@qq.com

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Abstract: With the continuous improvement of urban residents' lives, the demand for urban infrastructure construction increases, requiring more and more advanced engineering technology. We should not only speed up the progress of the project, but also reduce the impact of the construction on the surrounding environment. Our company has had several achievements in this regard, and prefabricated open caisson construction process is one of them. In this paper, the application of prefabricated caisson construction method is analyzed in depth according to the actual situation of the rain sewage reconstruction treatment project of Minghe ecological water system in Dancheng County. Through practice, it is concluded that this construction method greatly improves the construction efficiency, shortens the overall construction process, reduces the construction cost, and effectively improves environmental quality of the construction site, which has good reference value.

Keywords: Prefabricated open caisson; Open caisson construction

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1. Introduction

Prefabricated open caisson is a new form of open caisson, which can fundamentally facilitate the construction, reduce the excavation area and volume of work, and shorten the construction period. At present, the open caisson construction technology is divided into two types: one is vertical section; the second is transverse segmentation. The two methods basically adopt the same technology in the process of splicing assembly, that is, by setting the post-pouring belt to connect each piece. Each section should be reasonably applied pre-stress in the process of splicing, which can significantly enhance the tightness of the connection between the pieces and effectively improve the overall shear performance, in addition to effectively avoiding the problem of water seepage through the wall of the shaft. The construction process of this project is vertical segmentation, and the specific application of the prefabricated open caisson construction method is analyzed in depth as follows.

2. Project overview

The rain sewage reconstruction project of black and smelly water treatment project of Minghe Ecological water system in Dancheng County using prefabricated assembly work well. Its cross-sectional shape is rectangular, there are two parts, using the same structure and size, which can also be used as both jacking well and receiving well. Its specifications are as follows:

$$\text{Length} \times \text{width} \times \text{height} = 7000\text{mm} \times 5500\text{mm} \times 7500\text{mm}$$

Height direction of the well body is divided into three sections, and the connection between each section is made of vertical reinforcement, the height of 1# section is 2500 mm, the height of 2# section is 3000 mm and the height of 3# section is 2000 mm. The well body reinforcement is made of finely rolled steel, and the foot of the edge is treated as an aging section. A 500 mm long post-cast zone was set up and C50 concrete is poured. After the open caisson sinks to the designated position, the distance between the ground and the wellhead should be 2.5 m, the types of soil are mainly silty clay and clay, and the reference values of cohesion and internal friction angle are 20 MPa and 20° respectively.

3. Prefabricated open caisson construction

3.1. Lifting construction

3.1.1. Preparation

(1) Lifting order

The characteristics of the open caisson piece can be divided into two types, namely “[” type and “I” type. Based on the structure of the open caisson, the actual workload, etc., combined with construction safety and procedures, the installation section strictly started from the lower ring, then the middle ring, and finally the upper ring ^[1].

(2) Personnel, equipment, and materials configuration

The personnel include electricians, installers, surveyors, welders, and signalmen, of which, except for 6 installers, all others were 1 person, totaling 10 persons. The site was equipped with the following equipment: 1 crane for unloading and installation, 1 electric welder for rebar welding, 2 trailers for component transportation, 1 set of gas welding, 2 sets of vibrators for pouring and vibrating. The site was equipped with the following measuring equipment: 2 sets of latitude and longitude meters for verticality detection and control, 1 set of level meter for elevation control, 1 set of 50m steel ruler for axis measurement, 2 sets of steel horizontal ruler for horizontal measurement.

(3) Lifting machinery selection

Because the weight of a single piece reaches 26 T, according to the existing experience, the crane cannot be less than 80 T, thus, the project adopted a 100T car crane, its main parameters are as follows: (i) “[” type components—the rotation radius does not exceed 8m, the lower, middle and upper ring lifting weight is 17 T, 26 T, 22 T, the theoretical lifting weight is 41 T, and the length of its main boom is 17.4 m; (ii) “I” type components—the radius of rotation does not exceed 14m, the lifting weight of lower, middle, and upper rings are 7.5 T, 11 T, and 9.2 T, respectively, the theoretical lifting weight is 17.4 T, and the length of its main boom is 17.4 m.

(4) Measurement control and open caisson observation

Before the construction of the open caisson, the level base points, and control network was laid out. At the same time, the center point of the open caisson and the excavation construction range was determined in accordance to the relevant requirements of the drawings, and cross-line was placed in the surrounding area. If there was an existing building around, real-time observation points for settlement were created and observations ^[2] were carried out from time to time.

(5) Pit excavation

In order to minimize the actual excavation volume and occupy less land, a foundation pit with a depth of 1 m was first excavated by an excavator, and then a water collection pit was set up on the outside of it to allow precipitation.

(6) Mat construction

To avoid uneven settlement from the caisson installation after completion, the method of setting the bedding layer was used to strengthen it, so that the well was properly tilted. After leveling the bottom of the pit by hand, new gravel was laid on the center line of the open caisson, and the thickness was 150

mm, and the machine is used to tamp it after laying. Through calculation, the strength grade of concrete used in the bedding layer was C20, and the thickness was not less than 150 mm. In addition, the control line should be set according to the requirements of the drawings, which is the key to ensure the smooth progress of lifting [3].

3.1.2. Lifting machinery, components into the field

After the car crane comes into the site, its performance is checked comprehensively and must meet the lifting requirements. The ground endurance of the location of the car crane must meet the requirements, and the road can be used as the holding layer and a steel plate of 20 mm thickness is set at the four feet. At the same time, the components are checked in terms of appearance and size, etc. to determine whether the requirements are met.

The components are transported by car, and the transport should be matched with the progress of production and installation, and a reasonable transport plan should be made. When transporting the components, they must be placed smoothly, padded with liner if necessary, and fixed with twine to avoid sliding of the components during transportation, causing collision and falling. In the process of unloading, extra care must be taken to avoid damage and to adopt effective measures to prevent extrusion and collision.

3.2. Installation construction

The crane and the transporter are arranged on site in strict accordance to the drawings, and the lower ring of the open caisson is installed first and is fixed after installation is completed to prevent displacement when other members are installed. The member plate and the arc reinforcement is tied or welded. The welding method is one-sided lap welding, the required lap length is not less than 10 times the diameter of the reinforcement, and the welding seam should be full and keep even, so that the member has good integrity and avoid tilting [4].

After the lower ring is installed, the formwork support and concrete pouring is carried out. The formwork stiffness and all reinforcement knots should be sufficient to avoid problems such as rising of the formwork during the pouring process. C50 concrete is used for pouring, its collapse degree should be between 12–14cm, and the pouring height is 1.5 m. While pouring, we should use vibrating bar to vibrate evenly to avoid over-vibration and omission. After the construction of the lower ring is finished, the same method is used to construct the middle and upper rings.

3.3. Prestressing tensioning

3.3.1. Material preparation

The prestressing steel used in the construction must meet the current standard, and the tensile strength should be able to reach 1040 MPa. The steel used in the construction has a modulus of elasticity of 2.0×10^5 MPa, an elongation of 9%, and a cross-sectional area of 490.9 mm^2 . The anchorage and the corresponding supporting equipment should also meet the current standard. The galvanized metal bellows is used as the prestressing orifice, and the grouting construction is carried out by ordinary pressure grouting process, and its inner diameter is strictly controlled by 60 mm. A total of 44 pieces of fine-tied rebar of 2.5 m, 38 pieces of 3 m and 6 pieces of 0.5 m were configured on site; 50 sets of anchorages and 88 connectors were also configured [5].

3.3.2. Tensioning construction

Tensioning was performed by single end tensioning method with a tensioning control stress of $0.65 f_{pyk}$ and an under-anchor tensioning stress of 675 MPa. The force bars were tensioned at 330 kN, and the basic principle of symmetric tensioning was followed. The tensioning procedure was determined as follows:

0→1.03 times the tensioning control stress→1.0 times the tensioning control stress, and then the anchorage was held for 2 min. During the tensioning process, the stress control was given priority and the elongation value control was supplemented, and the deformation occurring in the well wall was fully considered, and the actual tensioning force of the force bars was mastered according to the sensor data. Before tensioning, all instruments and equipment were calibrated, while after tensioning was completed, necessary measurements and calibration were made. If the effective tensioning force did not meet the requirements, it was supplemented.

3.3.3. Borehole grouting

The middle ring of the open caisson is equipped with pressure grout hole, and the pressure grout should be carried out within 48 h after the completion of tensioning, and the pressure grout should become dense. The water-cement ratio of the slurry was 0.35–0.40. The amount of grouting agent can be adjusted according to the situation, while strength, fluidity and water secretion tests were carried out, and the 28 d compressive strength was required to exceed 30MPa.

3.3.4. Seal anchor

If the reinforcement on the sealed anchor end is too long, it is removed and then sealed with M20 cement paste.

3.4. Post-pouring zone construction

3.4.1. Mold support

The height of the mold support was 6 m, and the stiffness of the formwork and all the reinforcement joints should be firm to avoid problems such as mold rise during the pouring process.

3.4.2. Pouring

C50 concrete with a collapse degree of 12-14cm was used for pouring. Pre-excavated holes were opened at 4.5 m between the depth of the well and the bottom surface so that the vibrating bar could be inserted and vibrated. During the pouring, the vibrating rod must be inserted quickly and pulled slowly to ensure the continuity of construction, without interruption in the middle, otherwise the construction quality will be affected ^[6].

3.5. Open caisson sinking

3.5.1. Preparation

According to the existing geological data combined with the specific situation of the site, the sinking was carried out in an undrained way. In the sinking process, the long-arm hooker takes the soil from the center to both sides, and after forming a depression in the central part of the bottom of the shaft, the soil of the edge foot will be squeezed into it, and then continue to take the soil to ensure that the sinker continues to sink, and the sinking speed was kept within the range of 0.3-0.5m/d. Before sinking, the sinking coefficient was checked and the value 1.25 was used as a standard to ensure that sinking is completed successfully. If this requirement cannot be achieved, the sinking depth should be reduced, and additional loads can also be applied at the top of the well wall ^[7].

3.5.2. Open caisson sinking

The soil was excavated manually, lifted by electric hoist and loaded by hand truck. The soil taken out from the well shall not be stacked within 2 m of the well to prevent tilting due to the soil pressure becoming large. The soil was excavated continuously from the middle of the caisson to the four sides in layers. The

thickness of each layer was 0.4-0.5m. The soil bank was reserved around the edge foot, and then the cutting was carried out symmetrically and evenly along the shaft wall according to the interval of 2-3m. If the soil is compressed under the action of the edge, the caisson can enter the soil and avoid the formation of tilt. If there is little sinking, the excavation continues from the middle and continues to extend around. In addition, the soil beneath the cutting edge must be cleared in time to ensure that the sinking remains smooth.

When sinking, it is necessary not only to prevent uneven settlement and sudden settlement, but also to avoid deformation of the open caisson. In the process of internal excavation, the thickness of excavation is strictly controlled, and the excavation is carried out continuously from the middle to the surrounding area to ensure the symmetry and uniformity of excavation, while the soil platform is reserved for layer-by-layer cutting according to the actual requirements. After the caisson was sunk below the ground level, other processes were carried out, including reinforcement tying, mold support and pouring. The next round of excavation and subsidence was carried out when the strength of concrete was sufficient. The template was removed before the caisson entered the soil layer, and the soil collection stopped at a position 20 cm away from the designed depth for real-time observation. If the weight of the open caisson alone cannot sink to the specified depth, manual soil collection should be carried out slowly to ensure that the caisson reaches the required depth^[8].

3.5.3. Substrate cleaning and sealing

(1) Substrate cleaning

When the open caisson was 0.1m away from the design elevation, the excavation was suspended and the open caisson was sunk to the required elevation by its own weight, and the bottom was sealed after 2-3d of stability was maintained. After the open caisson is sunk to the required elevation, it is necessary to implement a comprehensive cleanup of the substrate and make preparations for sealing the bottom. In the process of bottom cleaning, the height of the bottom surface should be strictly controlled to avoid serious disturbance to the soil at the foot of the edge.

(2) Open caisson sealing

The bottom of the open caisson was newly paved with a pebble layer with a thickness of 150-500 mm, and then concrete was cast in place to form a bedding layer, especially below the foot of the edge, which was filled densely and vibrated evenly to keep the open caisson stable. After the strength reaches the requirement, the reinforcement was tied, and the ends of the reinforcement was stretched into the recess to pour the upper layer of concrete. The contact surface between the new and old concrete was rinsed with clean water and continuously pushed from all around to the central part, and the layer thickness was controlled within 30-50cm, while pounding evenly with a vibrator^[9].

In the process of sealing the bottom, the soil surface should be excavated to the design elevation, and if there is standing water in the well, it should be quickly removed. The position of the chisel hair should be washed, and uneven settlement should be avoided during the casting process. Besides, the soft soil layer should be done symmetrically in compartments, and before the concrete strength reaches the requirement, continuous pumping should be carried out, or take other stabilization measures.

3.6. Pipe jacking construction

Based on the guidance from from the relay station between the main top cylinder and the pipeline, the pipe jacking machine is pushed from the working well through the soil layer into the receiving well for hoisting, and the pipeline right behind the road heading machine is set between the two foundation pits, and the foundation pits are connected at the same time. The pipe jacking construction does not require any excavation except for the shaft, which means it occupies less land and does not affect the existing buildings, environment, and traffic. The key to controlling the topping force is to reduce the resistance to topping, and

the most common method is grouting. In addition, grouting can also form a lubricating jacket to reduce the frictional resistance during jacking.

4. Conclusion

Up to now, the open caisson construction of this project has been successfully completed, after inspection, the technical indicators and construction quality meet the requirements of the design and specifications, indicating that the proposed construction methods are reasonable and feasible. Besides, a reasonable application of the aforementioned methods can also shorten the construction period and improve the construction efficiency, indicating that it has good practicality.

Disclosure statement

The author declares no conflict of interest.

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