Construction Technology and Analysis of High and Large Formwork for Automobile Ramp

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Abstract. A square project in Hangzhou has the characteristics of high floors, deep foundation pits, large loads, and dense surrounding buildings and various municipal pipelines, which brought great difficulties to the construction, especially the formwork support part. This paper takes the construction of the tall formwork of the automobile ramp as an example to illustrate the design process and construction technology of the tall formwork of the project's automobile ramp. The rationality of the design of tall formwork was checked by PKPM software. The quality and safety monitoring measures of the construction process are also given.

1. Introduction
With the rapid development of my country's economy, large-scale buildings have been constructed in major cities. As a result, the application of Gao Da formwork support system in engineering has gradually increased and broadened. According to incomplete statistics, the incidence and death rate of collapse accidents of the formwork support system from 2011 to 2016 accounted for 30.38% and 33.55%, respectively. Therefore, this article analyses the construction technology of the tall formwork of a car ramp in a square in Hangzhou as an example, and provides a reference for the construction of tall formwork for similar projects.

2. Project Overview
The construction site of a square project in Hangzhou is located in Xiacheng District, Hangzhou. The total land area of the project plot is about 44,900 square meters, and the total construction area is about 386,000 square meters. The project plans to construct 6 42~150m high towers, 17~22m high commercial podiums and 5 floors underground. The underground construction area of the project is about 192,000 square meters, with a total of 5 basements, and the excavation depth of the foundation pit is about 28.4-29.7m. The surrounding buildings are 21.9m farthest from the foundation pit and 3.7m nearest; the underground pipelines of the project are complex and there are historical relics. Therefore, considering the complex environment of excavation of the foundation pit, in order to facilitate the excavation of earth, improve the efficiency of excavation, and speed up the construction progress, the soil excavation is carried out by increasing the slope of the foundation pit under the trestle bridge.

The car ramp is in the form of a ring foundation pit ramp, and the design height of the ramp is from the first to five supports, and is divided into a secondary ring ramp, as shown in Figure 1. The elevation of the primary loop ramp is -2.3 to -14.25m, and the secondary loop ramp is -14.25 to -
24.75m. The maximum elevation difference of the ramp is from the first to the second ramp, and the elevation difference is about 5.25m. During the construction process, the supporting beams affected the passage of vehicles, so they were lifted. The car ramp of the lower foundation pit adopts a beam-slab structure. After calculation, the concentrated line load of the member is 37.68 kN/m. The formwork support system that meets any of the following items is called a tall formwork support system. The support height exceeds 8m, or the erection span exceeds 18m, or the total construction load is greater than 15kN/m², or the concentrated line load is greater than 20kN/m² [2]. Therefore, the construction of automobile ramps requires the use of tall formwork, and this part of the slab support system is a sub-project that is more dangerous than a certain scale.

3. High and large formwork support design

3.1. Design general description

Combined with the geotechnical engineering survey report, the lower foundation pit ramp formwork system is set up in Area A of this project. The frame foundations are 1-3 layers of clayey silt, 2-1 layers of silty clay, and 3-1 layers of silty Clay and 3-2 layers of silty clay. Combined with the characteristics of soil quality, part of the soil is bad soil. In order to ensure that the foundation of the support is stable and the frame is stable, the frame foundation is reinforced. In accordance with the requirements of the enclosure drawing, two to five supports are provided with support strips. The pole can be supported on the support strip. The bottom of the pole is laid with channel steel or scaffold as the bottom pad to ensure the stability of the support.

In the process of formwork construction, follow the principles of reasonable economy, mature technology, reliable quality, simple operation and convenient turnover. The formwork is made of 15mm thick ordinary plywood, and the beam-slab formwork support frame mainly adopts the plate buckle type full house scaffolding.

According to requirements, steel-tube fastener-type scaffolds are not allowed to be used in the support system of sub-projects that are more dangerous than a certain scale. Therefore, the automobile ramp formwork supports disc-buckle scaffolding.

The vertical rod adopts 60 series disc rack, material Q345, and the wall thickness is 3.2mm; the cross bar adopts 48 series disc rack, material Q235, and the wall thickness is 2.5mm.

3.2. Selection and technology of ramp beam formwork

3.2.1. Beam formwork design

(1) Beam formwork beam axis position, section size and horizontal elevation should be accurate. An adjustable support (U-shaped support) is set on the top of the beam and slab support system. When the beam span is greater than 4m, it should be arched at 1/1000 ～ 3/1000 of the span, and when it is
greater than 8m, it should be arched at 3/1000 of the span. The cantilever beam is arched at 4/1000 of the cantilever length, and the arcing height is not less than 20mm;

(2) The secondary keel on the side of the beam is made of 50×70mm wood square, with a spacing of 200mm; the secondary keel at the bottom of the beam is made of 50×70mm wooden square, and the spacing is 150mm arranged along the length of the beam;

(3) The main keel on the side of the beam adopts 48×3.2mm double steel pipe @400mm; the main keel at the bottom of the beam adopts 48×3.2mm double steel pipe @400mm; the M14 pair of pulling screw @400.

(4) A diagonal pull rod is added under the adjustable bracket at the top of the bracket.

(5) All sweeping rods and horizontal rods are set up in both directions and shall not be omitted.

(6) The positional relationship between the beam bottom mold and the beam side mold, and the beam side mold and the beam side mold: the beam side mold wraps the beam bottom mold, and the top plate template presses the beam side mold.

(7) In the middle of the beam height on both sides of the beam, two additional steel pipe diagonal braces are added for each span to enhance stability. The diagonal braces should be connected with the bent frame poles. See Table 1 for other designs

| Table 1. Beam template design parameters. |
|------------------------------------------|
| **Erection type** | **Disc buckle type scaffolding** |
| Beam calculation parameters | Calculation section: 900×900/1000mm; calculation section area: 0.810 ㎡/0.900 ㎡ Installation height: 0~5.2m |
| Beam bottom formwork support form | Disc buckle type, shared by beam, plate and column |
| Template | Material: general rubber slab; elastic Young's modulus E': 6000; thickness (mm): 15mm |
| Upright stanchion | Steel pipe type 3Φ60×3.2（CalculationΦ60×3）, Laying of beams before slabs |
| Add a pole at the bottom of the beam | 2 2 |
| Support method of vertical pole at the bottom of beam | Adjustable bracket, 2 main flutes in the bracket, double fasteners on both sides |
| Longitudinal distance of beam bottom | 400mm 400mm |
| Beam Bottom Cross Distance | 600mm 600mm |
| Cross strut | One horizontal scissor brace is set every three steps; one vertical scissor brace is set every 5 cross straddle rods along the circumference of the frame and longitudinally |
| Base | Bottom of each upright stanchion Set the thickness of not less than 50mm bolster |
| Horizontal arm | Step distance Vertical step distance 1500mm |
| Side blow | Ground clearance 300mm, Vertical and horizontal continuous setting (Adjust according to different heights) |
| Main corrugated | Section type 3Φ48×3.6（CalculationΦ48×3.0） |
| Direction | Perpendicular to beam axis |
| Longitudinal spacing additional | 1 1 |
3.2.2. Beam formwork installation

(1) Technological process: making level, setting out (axis, horizontal line) → support erection → pillar head template → beam bottom template → tension line leveling (arching) → steel bar binding → sealing side mold.

(2) Template laying: adjust the elevation of the support column according to the design elevation and pull the line, and then install the beam bottom template. The beam is arched at three thousandths of the span length. When main girder and secondary beams are handed over, the primary beam is arched first, and then the secondary beam is arched.

3.3. Selection and technology of ramp board template

3.3.1. Ramp floor design

The thickness of the floor slab of this project is 300mm, and the support adopts disc buckle steel pipe scaffold + U-shaped brace. The distance between the support frame poles is 900×900mm, and the step distance is 1500mm. The sweeping pole has a height of 300mm from the ground, and is arranged vertically and continuously.

In order to ensure the stability of the frame, a full frame should be erected in accordance with the following regulations:

(1) The underlay of the vertical pole is adjustable. The size of the support is 150×150mm, and the thickness of the steel plate is 6mm. When the foundation height difference is large, the 0.5m node position difference can be used to adjust the adjustable base. The frame body should be erected after the floor or foundation reaches the strength.

(2) After each step of the frame is erected, the step distance of the horizontal rod, the vertical and horizontal distance of the vertical rod, the vertical deviation of the vertical rod and the horizontal deviation of the horizontal rod should be corrected in time. The vertical deviation of the vertical rod should not be greater than the total height of the formwork support 1/500 of and not greater than 50mm.

(3) When building a full-floor rack in multiple layers continuously, ensure that the upper and lower supporting poles are on the same axis.

(4) All sweeping rods and horizontal rods are set up in both directions, and shall not be omitted.

(5) There is no horizontal steel pipe scissor support in the internal area of the frame. Instead, the inclined rods of the disc buckle bracket are used. The top of the frame is covered with inclined bars to ensure the stability of the frame. The system layout, the diagonal rods are arranged in the form of lattice columns, and a lattice column is set every two spans.

(6) The design of this ramp is in the construction stage of the foundation pit. It is different from the use of connecting wall parts in the formal main structure construction. Considering the stability of the frame, this project uses the lattice columns that have been constructed to "hold the pillars". Column measures ensure the stability of the body, and the column holding setting is set every 2 steps. The holding column uses ordinary steel pipe fasteners to connect with the cross bar of the disc buckle bracket.

3.3.2. Ramp formwork installation

Process flow: setting out and applying for inspection → Set up the full space supports → laying the main steel keel → laying the secondary keel → laying the plywood surface layer → self-inspection → applying for inspection.

The construction process of the formwork system: measuring and setting out → Set up the full space supports → roof elevation measurement → installing beam bottom formwork → installing beam side form and slab formwork → steel bar binding → checking and accepting beam and slab reinforcement → pouring concrete → curing to design strength → Demoulding.
4. Construction technology control analysis

4.1. Template design checking calculation
In order to ensure the rationality of the design, the PKPM design software has been adjusted and tested, and the results of the verification are shown in Table 2. It can be seen that each component of the design of the tall formwork of the car ramp meets the requirements of the specification.

| Beam bottom template | Component            | Bending strength (N/mm²) | Shear strength (N/mm²) | Deflexion (mm) |
|----------------------|----------------------|--------------------------|------------------------|----------------|
|                      | Template panel       | 5.6<\[f\]=17             | 0.481<\[T\]=1.4        | 0.020<\[v\]=1.2 |
|                      | Beam bottom support keel | 5.08<\[f\]=17        | 1.332<\[T\]=1.7       | 0.102<\[v\]=1   |
|                      | Joist                | 140.6<\[f\]=205        |                        | 0.485<\[v\]=1.5 |

| Upright stanchion    | Stability: compressive strength of steel pipe 94.439 (No wind load) /125.78 (Wind load) <\[f\]=300 |

| Floor formwork support | Component            | Bending strength (N/mm²) | Shear strength (N/mm²) | Deflexion (mm) |
|------------------------|----------------------|--------------------------|------------------------|----------------|
|                       | Template panel       | 2.499<\[f\]=17           | 0.225<\[T\]=1.4        | 0.082<\[v\]=1   |
|                       | Support secondary keel | 7.44<\[f\]=17         | 0.868<\[T\]=1.7       | 0.676<\[v\]=2.25 |
|                       | Joist                | 128.51<\[f\]=205        |                        | 0.816<\[v\]=2.25 |

| Upright stanchion    | Stability: compressive strength of steel pipe 40.679 (No wind load) /41.601 (Wind load) <\[f\]=300 |

The calculation of the foundation bearing capacity meets the requirements.

4.2. Material quality control
Strictly check the incoming materials (steel pipes, fasteners, jacks, etc.), collect material certificates, factory certificates, relevant inspection reports, etc. of incoming materials in a timely manner, and conduct on-site inspections on the types, specifications, and visual quality of the materials. At the same time, witness sampling and inspection of incoming materials in strict accordance with the specifications. If defects such as poor apparent quality, cracks, or deformation of the incoming materials are found, they should be returned to the factory immediately, and the use of unqualified materials is strictly prohibited. All steel pipes are weighed before entering the venue to ensure that their weight and thickness meet the requirements before entering the venue.

4.3. Construction process monitoring and monitoring
Since the construction of tall formwork is a dangerous project that exceeds a certain degree of danger, the safety risk is high. In order to ensure the safety of construction and use, it is necessary to monitor the construction process.

Main monitoring items: frame displacement and deformation. Deformation monitoring is carried out with a total station and a level. In the entire process of pouring concrete, special personnel are arranged to conduct inspections and instruments to monitor the periphery of the frame. The monitoring personnel are strictly forbidden to operate under the formwork support system.

Monitoring frequency: Monitoring shall be implemented after the installation of the formwork support system; real-time observation shall be implemented during the concrete pouring process. Generally, the monitoring frequency shall not exceed once every 20-30 minutes; once the pouring is completed, the monitoring frequency shall be stopped after 24 hours, observe once every day.

4.3.1. Upright stanchion horizontal displacement and deformation value monitoring
(1) Determination of the maximum deformation unit of the upright stanchion
The maximum deformation element of the upright stanchion occurs within 1/3 of the mid-span of the frame beam and slab area, and a total of 2 vertical pole horizontal displacement observation points are set within the range.

(2) Observation method and determination of alarm value

Observe the deformation during the concrete pouring process. When the cumulative deformation value reaches 20mm and the deformation rate is $\geq 5\text{mm}/10\text{min}$, an alarm will be issued immediately and the construction will stop.

4.3.2. Construction load monitoring and control

(1) Monitoring and monitoring of construction live load

During the concrete pouring process, a dedicated person is arranged to monitor the construction live load. The two concrete pouring teams shall not be concentrated within 1m$^2$ for vibrating to prevent the formwork support system from collapsing due to the stress concentration phenomenon caused by the construction live load exceeding the limit. The construction live load must be arranged in strict accordance with the design load of the supporting system structure of $\leq 4\text{kN/m}^2$, that is, during concrete construction, no more than 4 people per team (calculated at an average of 75kg/person) and one plug-in vibrator for each team to carry out the concrete Pouring.

(2) Monitoring and monitoring of construction dead load

During the concrete pouring process, a dedicated person shall be arranged to strictly monitor the height of the concrete unloading pile not to be greater than 200mm.

4.4. Formwork removal control

Implement a template demolition approval system. Before the template is removed, it should be approved by the technical person in charge, supervised by the safety director, and reported to the supervisor for approval. The construction can only be carried out after the safety clarification of the corresponding parts is issued. When the high-supported part of the formwork of this project is dismantled, the strength and compression test of the test block under the same conditions shall be carried out in advance. The concrete strength must reach 100% of the design strength before it can be demolished. The dismantling process follows the principles of supporting first, then dismantling, and dismantling after supporting: dismantling the non-load-bearing formwork first, and then dismantling the formwork of the load-bearing part; from top to bottom, the support first dismantles the lateral support and then dismantles the vertical support.

5. Concluding remarks

This paper systematically explained the design process and construction process points of the super-hazardous high template for a car ramp in a square in Hangzhou. The strength and stability of the design were verified by the software, and they all met the requirements of the specification, and the material control during the construction process was given. The monitoring method of the main nodes of the template displacement and deformation, introduced the main control requirements of the template removal. It is hoped that the above content can provide a reference for the design, construction and maintenance of the same type of project.

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