Study on construction technology of hydraulic climbing formwork for super high-rise building under aluminum formwork system

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Abstract. The requirements for construction technology of super high-rise buildings are always at a relatively high level. With the rapid development of our society and the continuous improvement of scientific and technological strength, in recent years, the aluminum formwork construction technology and hydraulic climbing formwork construction technology in high-rise buildings and super-high-rise buildings have developed rapidly, and have been widely used in actual construction. The super high-rise building of this project adopts aluminum formwork+hydraulic climbing formwork system for core tube construction. This paper analyzes and studies the cooperation and application of hydraulic climbing formwork construction technology in core tube under aluminum formwork system, the safety of frame body and the treatment of special parts for readers' reference.

Keywords: Aluminum mold system; Super high-rise hydraulic climbing formwork: Core barrel; Safety of frame body.

1. Introduction

Aluminum formwork has the characteristics of lightweight, flexible disassembly and assembly and high rigidity. It is superior to traditional wooden formwork in material, construction effect, service life, environmental protection, etc. It can improve engineering quality, speed up construction period, and avoid human error in construction. Except for construction waste generated during pouring, there is basically no residue after formwork removal.

Hydraulic climbing formwork is a multi-functional attachment device with many functions, such as attachment, guidance, anti-overturning, etc. In building construction, hydraulic jacking is used as power, and it climbs layer by layer with the height change of structure construction. From the structural point of view, the hydraulic climbing formwork system is usually composed of climbing system, formwork system and working platform system. The climbing system includes climbing frame, embedded parts system, guide rail, hydraulic system, etc. The hydraulic jack is the key to alternate climbing of the whole system.

In this project, aluminum formwork system and super high-rise hydraulic climbing formwork technology are combined. Through the research on the construction technology of super high-rise
hydraulic climbing formwork under aluminum formwork system, the technical problems of aluminum formwork and climbing frame in super high-rise construction are solved, and the advantages of all parties are compared economically, so as to improve the overall construction efficiency, safety effect, quality effect, economic benefit and environmental benefit, and provide powerful technical support for the smooth application of super high-rise aluminum formwork and climbing formwork.

2. Engineering survey
The No.23 and No.24 plots (Lanshihao Busca N District) of the old factory reconstruction project of Lanshi Group are located at No.194 Xijin West Road, Qilie District, Lanzhou City, which is connected to B198# of Planning Road in the east, Xijin West Road in the south, T196# of newly-built municipal road in the west and 123# of Planning Road in the north. It covers an area of about 54991.6m², with two underground floors (three local floors), three above-ground podium buildings, 26-29 residential buildings, 13 hotel floors, 15 floors of comprehensive office building A and 31 floors of comprehensive office building B. The total construction area is 316,000 m², with an above-ground construction area of 219,700 m² and an underground construction area of 96,300 m². Comprehensive office building b is a frame core tube structure with a standard floor height of 4.20m and a building height of 148.3m

![Figure 1](image.png)

3. Selection of layout scheme of hydraulic climbing formwork system

3.1. Selection of layout scheme
This project adopts the construction method that the horizontal and vertical structures of the core tube are constructed at the same time. The external wall of the core tube is equipped with hydraulic climbing formwork, and the peripheral aluminum alloy formwork can be hoisted into the formwork support system of the external wall climbing formwork. After installation, the external wall aluminum formwork can climb with the frame body at the same time, saving the times of lifting the formwork by tower crane. At the same time, the top layer of the frame body can stack materials, and the top platform can carry materials of 400kg/m², which can basically meet the stacking and use of the whole layer of steel bars. This process solves the problem that the use and allocation of labor, machinery and equipment, production materials and other factors are very restricted. At the same time, the horizontal floor and the core tube stairs are constructed at the same time, giving attention to safety. In case of emergency such as power failure and fire, workers can escape and save themselves through the horizontal floor and stairs.
3.2. Layout
According to the structural characteristics of this project, the hydraulic climbing formwork is arranged on the outer wall of the outer wall of the core tube. After the completion of the vertical wall on the second floor of the core tube, the hydraulic climbing formwork is installed, and the third floor of the core tube is put into use. The lifting of the climbing formwork can be completed in sections, sections or as a whole. The external wall hydraulic climbing formwork has 22 seats and 4 sets of frame bodies.

![Figure 2](image-url)

**Figure 2** Layout plan of hydraulic climbing die for core barrel

4. Selection of climbing form (by calculation)

4.1. Design of climbing formwork system
The hydraulic climbing formwork of the external wall (JFYM100 type) of this project is mainly composed of lower frame, upper frame, formwork support, hanger and hydraulic equipment; Applied to the construction of 3~ (th) roof layer structure of core tube, the design of frame body completely avoids the embedded parts of openings and steel beams, without any auxiliary reinforcement measures. The frame body shall be embedded after the binding of steel bars in the vertical structure of the 2nd floor (elevation of the 3rd floor: 12m), and the frame body shall be hoisted after the concrete construction is finished and the formwork shall be removed after the structure is constructed to the roof layer (elevation: 136.4m).

15 platform steel beams and 10 joists (all platform steel beams are 14# I-beams) are used to connect the positions of the external wall hydraulic climbing formwork, and they are fixed with U-shaped bolts, which ensures the strength, stiffness, stability and integrity of the formwork to the maximum extent. All the assemblies are modular, which can be assembled on the ground and lifted integrally. The lower frame, guide rail and anti-falling climber are assembled before leaving the
factory. Climbing equipment adopts a complete set of standardized design, and the equipment enters
the construction site and is integrally assembled and then hoisted in place, without secondary
processing on site. The standardized design is easy for installation, construction management and
process control, which is more conducive to construction safety. The equipment side protection adopts
"steel frame+steel mesh+rice steel bracket", and the bottom protection adopts "steel frame+steel plate"
all-steel external protection, which is flame retardant, leak proof and wind resistant at high altitude.
According to the special construction process such as limb, corner, variable cross-section and cross-
use of other construction machines and tools, the structures such as flap, sliding door protection and
special protection channel are designed to ensure the construction safety. Equipment design special
anti-falling device and anti-overturning device, with double protection.

4.2. Configuration form of aluminum template
(1) The structure of this project has different storey heights with the change of the number of floors in
the main building, most of which are 4.2 m high. It is necessary to configure the aluminum template
standard board according to the 4.2m height of the standard floor. On the 4.3m, 4.35m, 4.4m and 5.0m
floors, the vertical wall column template is heightened by aluminum-wood combination construction
technology, and the concrete of the core tube beam slab is cast in place at one time.
(2) Considering the construction characteristics of this project, the aluminum formwork quick-
release system is combined with the climbing formwork construction technology, the core tube is cast
in place in the whole layer, and the aluminum formwork quick-release system is used to improve the
turnover rate and reduce the construction period of wood formwork splicing and post-practice. The
configuration of aluminum formwork shall be reasonable, and the construction concrete of aluminum
formwork shall have good appearance, smooth structure surface and clean joints everywhere.
(3) Considering the particularity of climbing formwork technology, the beams and slabs of the
outer frame floor generally lag behind the core tube by 6~8 floors, so the post-construction method is
adopted. Steel columns and beams should be reserved and embedded in the beams and plates of the
core tube and outer frame, which have different construction difficulties from climbing formwork and
aluminum formwork, which are described in detail in subsequent chapters.
(4) The composition of aluminum formwork system includes standard plate, internal angle mold,
external angle mold, additional back stare blankly, back stare blankly hook, through-wall bolt,
butterfly nut, cross plate, pin, pin plate, pin plate, etc. Climbing formwork is connected into a whole
by standard bolts, and is completely dismantled and assembled. The stress system of "well" lattice
formed by the back of aluminum formwork is reasonable.

4.3. Selection of climbing form
(1) Basic conditions
According to the actual material type, structure form and cross-section form of bar element, a
three-dimensional spatial model is established by using finite element midas finite element analysis
software. Use midas Civil2019 software to carry out spatial 3D modeling and spatial finite element
analysis on the first frame in the above figure.
1) The horizontal spacing of wall-attached devices on adjacent aircraft positions is 3400mm, 5000
mm, 5150 mm and 1450mm; respectively.
2) Floor height (spacing between upper and lower wall bolts): 4200mm;
3) Template size (height× width): 4280×5075mm;
4) Template size of the hole (height× width): 3400×3300mm;
5) Elevation dimension (height× width) of safety net (steel net) above formwork (weight of
aluminum formwork: 55kg/m²): 4811×5075mm;
Establish the model as shown in the following figure:
(2) Mechanical load analysis

There are three working conditions in the process of climbing frame construction: the first is normal construction condition; The second is climbing working condition; The third type is shutdown condition. According to the analysis, the climbing frame bears the greatest load in the normal construction process, which is the most unfavorable working condition.

The frame is in a static state, and the loads at this time include constant load, construction live load and wind load. The values of each load according to the actual construction are as follows:

1) Constant load

   The standard value of constant load of frame steel structure is calculated according to the size of bar and material density.

   The standard weight of steel platform system planking is 0.4kN/mm²
   The standard value of dead weight of the outer maintenance steel mesh (including keel) is 0.055 kN/mm²
   The standard value of dead weight of formwork system is 0.4kn/mm²

2) Live load

   Construction load of upper operating platform: 5kN/m²
   Construction load of lower operating platform: 1kN/m²

3) Wind loading

   Take the basic wind pressure value:

   \[ w_{k71} = \frac{\beta_{g_s} \mu_s \mu_c \alpha_0}{1600} = 1.63 \times 0.78 \times 1.79 \times 0.183 = 0.42 \text{ kN/m}^2 \]

   \[ w_{k72} = \frac{\beta_{g_s} \mu_s \mu_c \alpha_0}{1600} = 1.63 \times 1 \times 1.79 \times 0.183 = 0.53 \text{ kN/m}^2 \]

   \[ w_{k9} = \frac{\beta_{g_s} \mu_s \mu_c \alpha'_0}{1600} = 1.63 \times 0.78 \times 1.79 \times 0.372 = 0.847 \text{ kN/m}^2 \]

   In which:

   \[ w_0 = \frac{v_0^2}{1600} = \frac{17.1^2}{1600} = 0.183 \text{ kN/m}^2 \]

   \[ w'_0 = \frac{v'_0^2}{1600} = \frac{24.4^2}{1600} = 0.372 \text{ kN/m}^2 \]

   Among them, \( v_0 = 17.1 \text{ m/s}, \quad v'_0 = 24.4 \text{ m/s} \).

   In GB50009-2012, the ground roughness is divided into four categories: A, B, C and D. The area where this project is located belongs to Class C ground, so look-up table shows:

   \( \beta_{g_s} \)—Gust factor is taken as 1.63, which is 150m high, class c ground.
—The wind load shape coefficient of the frame body and the ratio of the windproof area/windward area between the dense mesh safety net and the scaffold are calculated as 0.78.

—The variation coefficient of wind pressure height is taken as 1.79, which is 150m high, class c ground (p42).

Wind load standard value:

Working conditions of construction:

\[ W_{k7} = w_{k71} \times 4.811 \times 5.075 = 0.42 \times 4.811 \times 5.075 = 10.255 \text{ kN} \]

4) Combination of load conditions

The load standard value and partial coefficient of climbing formwork device shall be specified in the following table:

| Items and times | Load category | Load standard value | Partial safety factor for load |
|----------------|---------------|---------------------|-------------------------------|
| 1              | Self-weight of formwork climbing device | G_k                | 1.2                           |
| 2              | Construction load of upper operating platform | F_{K1}            |                               |
| 3              | Construction load of lower operating platform | F_{K2}            | 1.4                           |
| 4              | Construction load of crane platform | F_{K3}            |                               |
| 5              | Wind loading | W_k                |                               |

Load combination list

| Serial number | Name       | Activate | Type   | Illustrate | Load case      | Coefficient |
|---------------|------------|----------|--------|------------|----------------|-------------|
| 1             | Loading combination | Inactivating | Adding |            | Dead load(ST) | 1.200       |
| 2             | gLCB       | Activate | Adding | 1.2D+1.4L  | Live load(ST)  | 1.400       |
| 3             | gLCB       | Activate | Adding | 0.9D+1.4L  |                |             |
| 4             | gLCB       | Activate | Adding | 1.2D+1.4L  |                |             |
| 5             | gLCB       | Activate | Adding | 0.9D+1.4L  |                |             |
| 6             | gLCB       | Activate | Adding | D+L        |                |             |
| 7             | STL        | Activate | Envelope | Steel Strength Env |              |
| 8             | STL        | Activate | Envelope | Steel Serviceability |            |

**Figure 4** List of load combinations

Among them, the live load in the process of model load value includes wind load, crane platform construction load and upper and lower operation platform load, and the dead load is the dead weight of climbing frame.

(3) Establishment of finite element model

Basis for establishing the model

In this project, wall-attached hydraulic climbing form is adopted. According to the structural characteristics of climbing frame, a finite element model is established based on finite element soft
midas Gen The model diagram is established by simulating the dimensions of each bar according to the actual bar arrangement.

Calculation results and analysis of the model

![Internal force diagram of climbing frame under normal construction conditions (unit: KN.m)](image1)

**Figure 5** Internal force diagram of climbing frame under normal construction conditions (unit: KN.m)

![Stress diagram of climbing frame under normal construction conditions (unit: MPa)](image2)

**Figure 6** Stress diagram of climbing frame under normal construction conditions (unit: MPa)
Figure 7  X-direction displacement diagram of climbing frame under normal construction conditions (unit: mm)

Figure 8  Y-direction displacement diagram of climbing frame under normal construction conditions (unit: mm)
Figure 9 Z-direction displacement diagram of climbing frame under normal construction conditions (unit: mm)

As shown in the above figure, it can be seen that under normal construction conditions, the maximum stress on the climbing formwork body member is 94.4MPa, and the maximum stress is located at the bolt attached to the wall of No.3 machine seat, which is 215MPa less than the design strength of steel. The maximum horizontal displacement in X direction is 0.137mm, the maximum horizontal displacement in Y direction is 0.027mm, and the maximum vertical displacement is 1.513mm. The vertical maximum displacement position is 14 I-beams on the main keel of the upper operating platform, with a total length of 19.6m and a maximum allowable deflection of 19.6 * 1000/400 = 49 mm. The overall displacement of the climbing formwork body is small and the deformation is relatively uniform, which can meet the requirements.

(4) Calculation of bearing capacity, coagulation punching and local compression of external wall bolts of core tube

The external wall is connected by pressure-bearing high-strength bolts of 6.8 grade and tapered bearing, with a diameter of 48 mm.

Figure 10 Normal construction bearing capacity diagram of climbing frame body

According to the calculation results, the bolt is subjected to the combined action of shear force and tensile force, and the maximum shear force design value is 102.6KN and the maximum tensile force design value is 29.2kN.

The shear bearing capacity of each high-strength bolt is in accordance with Code for Design of Steel Structures GB50017-2017: Formula 7.2.1-1.
Nvb=Ae*fvb=1808X250=452kN

The tensile bearing capacity of each high-strength bolt is in accordance with Code for Design of Steel Structures GB50017-2017: Formula 7.2.1-5:

\[ N_{tb} = \pi d^2 f_{tb} / 4 = 3.14 \times 48 \times 48 \times 400 / 4 = 723.4kN \]

Actual shear force of each high-strength bolt:

\[ N_v = 102.6 / 2 = 51.3 \text{ kN} \]

Actual tension of each high-strength bolt:

\[ N_t = 29.2 / 2 = 14.6 \text{ kN} \]

According to JGJ195-2010, technical specification for hydraulic climbing formwork engineering, formula B.0.1, the high-strength bolt is subjected to the combined action of shear and tension, and meets the following requirements:

\[ [(N_v / Nvb) ^2 + (N_t / Ntb) ^2] ^{0.5} = 0.114 < 1 \]

Through calculation, it can be known that the external wall adopts pressure-bearing high-strength bolts of grade 6.8 to meet the requirements of bearing capacity.

Local compression calculation of the interface between external wall bolts and concrete

The thickness of concrete wall is 400mm, \( h_b = 350 \text{ mm} \), and the attachment scheme of through-wall bushing type is adopted. The backing plate on the inner side of the wall is 140 mm × 140 mm × 12 mm. When the concrete strength grade is C15, the design value of axial tensile strength (punching shear capacity) is \( f_s = 0.91 \text{ N/mm}^2 \). (Local compressive bearing capacity) The design value of axial compressive strength is \( f_c = 7.2 \text{ N/mm}^2 \).

Punching bearing capacity

\[ F_s \leq 2.8(a + h_b) f_s h_b = 2.8 \times (140 + 350) \times 0.91 \times 350 = 436.982kN \]

According to the above analysis, the maximum shear force and pressure of the external wall are 102.6kN and 29.2kN, respectively.

Namely 102.6 \leq 436.982kN

Local compressive bearing capacity

\[ F \leq 2.0a^2 f_c = 2 \times 140 \times 140 \times 7.2 = 282.24kN \]

Namely \( F_a = 29.2 \leq 282.24kN \)

The bearing capacity of concrete meets the requirements.

5. Strengthening measures and safety protection technology of frame body tension connection

5.1. Strengthening measures of frame body pull connection

The cantilever end is above the main bearing point of the hydraulic climbing formwork. In the structural construction stage, the upper frame must be connected with the main bearing point. The upper frame and the reserved anchor or main structure in the structure should be rigidly connected and fixed, and the horizontal spacing of the connection should be controlled within 3 meters. If the machine seats are arranged inside and outside the wall, the upper frame of the inner and outer frame bodies shall be rigidly connected, and the upper and lower tension strengthening bars shall be arranged every 3m in the horizontal direction. Now, the strengthening measures of frame pull connection under different conditions are respectively expounded:

1. The frame body is in the installation stage

When the frame body is in the installation stage, because the height position of the frame body is low, and it is less affected by wind, the installed frame body must be closed in time, and all the template bolts should be fastened in place. On average, two steel pipes should be used every 3 meters to pull and fix the cantilever end of the upper opening of the frame body template.

2. The frame body is in the state of closing mold and pouring concrete
In this state, all formwork counter bolts of the hydraulic climbing formwork system are in a fastening state, and the cantilever end height of the frame body is reduced by 2/5. In this state, the cantilever end of the frame body is required to be fixed by upper and lower steel pipes every 3m on average, with the first one at the upper mouth of the formwork and the second one at the middle of the cantilever end of the frame body.

(3) The frame body is in the mold opening soon, the upper wall attachment device is not installed, and the guide rail is not climbing
In this state, in order to reduce the height of the cantilever end, the formwork can be brought close to the wall again, and the upper, middle and lower formwork bolts should be tightened. At the same time, the cantilever end of the frame body should be fixed by upper and lower steel pipes every 3 meters on average, with the first one at the top of the formwork and the second one at the middle of the cantilever end of the frame body.

(4) The frame body is in an open mold state, the upper wall attachment device has been installed, and the guide rail has climbed
In this state, the frame body is at a disadvantage. If time permits, climb all the frame bodies as soon as possible, close the mold at the first time, and fasten all the template bolts in place, and then pull and fix the frame bodies according to the above-mentioned pull and connect principles.

(5) The frame body is in the process of climbing
When the frame body encounters severe weather in the process of climbing, on the premise of time permitting, if the frame body is close to climbing, the frame body will be quickly closed and reinforced after climbing into place, and the cantilever end of the frame body will be fixed by pulling; If the frame body begins to climb soon, lower the frame body to the next construction layer, insert a flashboard to fix the frame body with the structure, and pull and fix the frame body according to the above-mentioned principle of horizontal spacing of 2m.

(6) The frame body is in the dismantling stage
When the frame body is in the dismantling stage, in case of bad weather, the dismantling operation must be stopped. If the template has been removed from the frame body, the cantilever end of the frame body must be fixed by pulling with three steel pipes every 3 meters on average in the horizontal direction; If the formwork is not lifted away from the frame body, the formwork shall be reinforced by three formwork bolts, and the cantilever end of the formwork upper opening of the frame body shall be pulled and fixed by two steel pipes every 3m on average in the horizontal direction.

5.2. Safety protection technology
(1) Protection design of frame body
   1) Overall horizontal protection design of climbing formwork
      The climbing formwork system is equipped with six platforms, and the hydraulic climbing formwork system is equipped with six platforms. The platform plates of each layer are all shaped steel springboard, and some parts are filled with patterned steel plates. Patterned steel springboard has the functions of fire prevention, skid resistance and corrosion resistance.
      2) Protection between climbing formwork and building structure and protection between formwork
      On the horizontal beam frame of climbing formwork, the platform plate shall be laid, and the distance between the platform plate and the concrete wall shall be greater than 200mm. Every independent frame body shall have a clearance of not less than 100mm during erection to ensure the climbing of the independent frame body.
      ①Climbing formwork reinforcement operation layer is protected by setting upper and lower protective railings inside.
      ②A folding platform is set at the position where the platform flap of the template operation layer is close to the template. When the template is closed, the folding platform can be opened, so that personnel can operate the template with the help of this platform. When opening the mold, the folding platform will be put away to ensure that the template has enough mold withdrawal distance.
The platform plate at the bottom of the frame body must be laid tightly. Set the flap structure that the bottom platform plate can be folded when the frame body is lifted, and the gap between the bottom platform plate of the cage body and the outer wall surface during lifting and normal use to prevent materials from falling. When the frame body climbs, the flap will be turned over. After the frame body climbs in place, the flap should be laid immediately.

Push-pull corner protection net is used for corner protection on the facade of climbing formwork. This type of protective net can be adjusted according to the cross-section change of the core tube, which will not cause interference in the protection of the machine body due to the variable cross-section of the wall, and can seamlessly protect the corner of the frame body.

Connection of each operating platform of climbing formwork
Personnel up and down passages are set between platforms of climbing formwork system, steel stairs of climbing formwork on outer wall of core tube are set as inclined ladders, and guardrails are set around openings of up and down passages. When the frame body is assembled or the platform plate is perfected, a gap of 1500mm shall be reserved at the corresponding frame body position of each wall, and a set steel ladder shall be built to connect the platforms, so that there is a channel up and down the frame body, and protective railings shall be made at the openings of the platforms.

3) External protection
1 Facade protection
The external facade of the core tube climbing formwork is provided with a steel protective net, which is rigidly connected with the frame body through the channel steel joists, giving all the working faces of the frame body full-enclosed protection. The steel net adopts the assembling type, which can be integrally hoisted after the ground assembly is completed.
2 Corner protection
In this project, push-pull corner protection net is used for corner protection of external wall climbing formwork. This type of protective net can be adjusted according to the cross-section change of the core tube, which will not cause interference in the protection of the machine body due to the variable cross-section of the wall, and can seamlessly protect the corner of the frame body.

2 Safety protection system
1) Anti-falling mechanism of hydraulic climbing formwork
The climbing mechanism of climbing formwork is mainly composed of guide rail with climbing step block, upper and lower anti-falling climbers and hydraulic oil cylinder attached to it, which are connected with the vertical lower frame of climbing formwork as a whole through the connecting shaft at the upper end of the upper anti-falling climber. The upper and lower anti-falling climbers are provided with cam pendulum blocks (herringbone pendulum blocks or bearing blocks) and linkage guide wheels which can guide automatically.
When the guide rail or frame body climbs, the oil pump is started. Through the expansion and contraction of the oil cylinder, the cam swing block and the guide wheel in the upper and lower anti-falling climber automatically change direction, automatically guide, automatically reset and automatically lock along the step block on the surface of the H-shaped guide rail, so as to achieve the climbing of the frame body.
The cam swing block in the anti-falling climber can automatically guide and reset. In the actual lifting process, there is always a bearing block in the anti-falling climber alternately supported on the guide rail step block, which is essentially both a climbing mechanism and an anti-falling mechanism.
2) Anti-tilting device
There are two sets of anti-tilting devices for climbing formwork, which are insert plate and support leg. The guide rail always passes through two wall-attached devices, which have anti-overturning function. At the same time, there is a locking plate in the wall-attached device at the main bearing point, which controls the inclination distance of the guide rail; The frame body embraces the guide rail through the upper and lower anti-falling climbers, which can prevent the frame body from tilting when the frame body climbs and is fixed. The legs of the operating platform of hydraulic climbing
formwork support on the structure, which is the second set of anti-tilting mechanism of hydraulic climbing formwork.

3) Lightning protection of climbing formwork
   In the process of structural construction, the position of climbing formwork is always lower than the height of tower crane, and the lifting of tower crane always takes precedence over the climbing of frame, so the frame is always in the coverage of tower crane, so there is no need to install lightning arrester module for lightning protection.

   The main grounding module of the climbing formwork is the wall-attached device of the formwork, with two groups at each position, which are welded and fixed with the wall reinforcement and grounding reinforcement through the embedded sleeves, and then embedded into the building body through the wall bolts of the climbing formwork, thus achieving the grounding effect.

   The protective net on the facade of the climbing formwork and the frame body are all-steel welded parts, which are fixed by inserting and anchoring, and can share a set of lightning protection devices with the frame body, thus playing a role in preventing side impact lightning. The frame body protective net crossbar and joist can be used for fixing and grounding the electric box on the construction site.

4) Fire and rescue passage for climbing formwork
   Set fire pump pipes longitudinally along the external wall of the structure; Each group of frame bodies is equipped with fire extinguishers; Because the horizontal structure and vertical structure of the core tube of this project are constructed synchronously, if there is a fire or other dangerous situation on the climbing formwork or the construction working face, all personnel can climb the formwork directly down to the structural stairs for evacuation.

5) Communication and signal security
   Operators of climbing formwork shall be equipped with walkie-talkies. During the construction of climbing formwork, operators of climbing formwork shall communicate through walkie-talkies. In the process of climbing formwork, walkie-talkies should also be used for communication between the operation platform and the station safety officer on the operation surface, and a special channel for climbing formwork operation should be set in advance. It is forbidden to use this channel for communication and contact in matters related to non-climbing formwork operation and construction.

3) Important node protection
   1) When the hydraulic climbing formwork is arranged across the doorway, protective railings shall be installed inside the climbing formwork system (near the wall surface) to prevent people from falling.
   2) Protection of stair openings in climbing formwork system Protective railings are welded on three sides of stair openings.
   3) Skirting boards are arranged on the upper two platforms of the frame body, and rear sealing boards are arranged on the main platform, the upper two platforms and the hanger layer to prevent scattered objects from splashing out of the platform after landing, which is neat and beautiful.

6. Key technical difficulties
The core tube of this project adopts cross-shaped steel column+shear wall structure system. There are four “╋”-shaped rigid steel columns at the four corners of the core tube. The steel column and shear wall of the core tube are connected with the outer frame of the main building by steel beams, and the steel beams between the inner and outer frames are connected by bolts. The thickness of the core tube wall changes greatly, and the thickness of the wall gradually changes from 800mm to 400mm in a gradient of 100mm, so it is very difficult to climb the formwork.

1) Treatment of leg parts
   At the four corners of the core tube structure above the second floor of this project, the bracket of steel structure extends out of the wall by 515mm, and the bracket position template needs to be lifted away from the frame body. Instead, the bracket position is constructed by using scattered aluminum formwork on site. Choose JFYM100 type frame body, and the first type steel beam of the frame body
is 540mm away from the wall surface, so it is only necessary to reserve the platform plate at the corresponding position of corbel for turning over, and then climb normally.

![Figure 11](image1.png)

**Figure 11** Schematic diagram of corbel connecting steel column and steel beam

![Figure 12](image2.png)

**Figure 12** Model drawing of climbing formwork and turning plate at the connecting bracket of steel column and steel beam

After the installation of the climbing formwork truss is completed, the climbing formwork beyond the platform beam of the corbel shall be removed locally. First, cut off the platform plate at this position, weld it with long steel bars, and pick out the position to overlap with other platform plates, which is more convenient for operation. When the corbel passes, evacuate the cut platform plate. The platform beam shall be supported horizontally and vertically at the position where the corbel passes, and then the main beam of the platform beam at the corbel position shall be cut off. After the frame platform climbs through the corbel, the protection of platform beam and platform plate shall be restored in time.

(2) Combined construction technology of hydraulic climbing formwork and aluminum alloy formwork

1) Connection node between external wall hydraulic climbing formwork system and aluminum formwork

The external wall hydraulic climbing formwork itself has a formwork withdrawal device, so it is necessary to connect the aluminum formwork with the formwork withdrawal device. First, it is necessary to assemble the aluminum formwork into a whole, and then four positions of each machine seat are fixed with the aluminum formwork and one auxiliary connection is made to ensure that the aluminum formwork is firmly connected with the frame body without dislocation. The four connections are as follows: three groups of template hooks on each seat are connected with the 4th, 6th and 7th back ridges on the template, and the back ridges welded by channel steel are held under the 6th back ridge on the aluminum mold, and a stop is set to prevent the template from slipping out; one auxiliary back ridge welded by channel steel is set under the 3rd back ridge on the aluminum mold to ensure that the template and the die withdrawal mechanism are tightly attached, and the aluminum template and the frame body are firmly connected without dislocation.
Figure 13 Schematic diagram of the combination of climbing die and stripping device and aluminum die

Requirements for aluminum formwork: the corresponding four back edges of aluminum formwork are changed to 10# channel steel (buckle at the back edge position under the frame body and fix the position of the formwork with formwork hooks in three ways), so that the aluminum formwork can be buckled on the back edge under the frame body to prevent it from coming out; Back-edge splicing of aluminum formwork and opposite screw holes should avoid formwork support columns, so as to ensure that the formwork and formwork withdrawal mechanism are tightly attached; The shuttering system of climbing formwork provides shuttering and adjusting platform for formwork. It is forbidden to adjust the verticality of formwork itself with adjusting legs, and it is forbidden to use climbing formwork to pull hard and support the formwork.

Figure 14 Effect drawing of combination of stripping device and aluminum die

Figure 15 Connection effect drawing of pull rod between aluminum mold and climbing mold base
(3) Combined construction technology of climbing formwork and tower crane

1) Tower crane layout

This project is equipped with a flat-arm tower crane. As the tower crane is arranged outside the outer frame of steel structure, there is no conflict between the layout of hydraulic climbing formwork and the anchoring position of the tower crane.

2) Relationship among tower crane, steel structure and climbing formwork

Rules for cooperation construction of climbing formwork, tower crane and steel column are as follows: on the premise that the top of the frame body will not collide with the balance arm and counterweight of tower crane, the frame body will climb to the designated position. When the frame body climbs in place, it is necessary to ensure that the upper opening of the formwork is lower than the elevation of the top of the steel column, which is convenient for pouring wall concrete and installing and welding the steel column. At this time, the bottom of the frame body should be higher than the top of the climbing beam of the tower crane, then install the climbing beam on the top of the climbing tower crane to prepare for the lifting of the tower ceiling, and then lift the tower crane.

The simulation diagram of climbing formwork and tower ceiling is shown as follows:

![Figure 16 Simulation diagram of climbing formwork and tower ceiling](image)

In order to ensure the smooth cooperation between the tower crane and the hydraulic climbing formwork, the free height of the tower crane must be greater than the distance from the top of the hydraulic climbing formwork to the top attachment point of the outer frame structure tower crane. When the construction rhythm cannot guarantee this requirement, it is necessary to increase the extension arm of tower crane to temporarily attach the tower crane to the core tube structure, and then carry out jacking operation.

(4) Treatment technology of construction platform for formwork reinforcement layer

The third platform in the hydraulic climbing formwork system has a narrow passage because the formwork withdrawal distance should be taken into account, so the formwork reinforcement operation cannot be carried out with this platform during the formwork closing stage. According to this characteristic, the hydraulic climbing formwork system is optimized. A folding platform is set near the formwork, and the folding platform is opened when the formwork is closed, so that personnel can operate the formwork with this platform. When opening the formwork, the folding platform is put away to ensure that the formwork has enough withdrawal distance.

In order to ensure that the operating platform has enough bearing capacity, the turning platform is horizontally connected, and the turning platform is vertically connected with the horizontal main girder of the frame body.

(5) Comparison and selection of cloth machine layout

1) Manual distributor: use tower crane to hoist the distributor to the construction floor every time concrete is poured, and then hoist it to the open space for the next pouring.
Figure 17 Use simulation diagram of manual material distributor

Technical features:
① As the main load-bearing unit of the distributor, the vertical support of aluminum mold conducts the vertical force.
② The construction is flexible, and it can be used with the crane.

2) Hydraulic automatic climbing material distributor: holes are reserved in the climbing platform, and the hydraulic self-climbing material distributor is installed on the substructure, so that the material distributor can climb along with the structure.
Technical features:
① The lower floor is used as the bearing unit of the spreader platform, and it is necessary to push back the floor to meet the requirements of the spreader's bearing capacity.
② The horizontal attachment support adopts the floor attachment frame, which transmits the horizontal force of the distributor to the floor level to ensure the horizontal stability of the distributor.
③ With the construction progress, hydraulic pressure is used as power to carry out self-climbing of the distributor.

3) Integration of spreader platform and die climbing platform: A steel platform which can be lifted along with the change of structural height and die climbing is designed on the internal promotion frame of the elevator shaft of the die climbing core tube as a supporting platform for the whole weight of spreader, and the die climbing lifting frame and spreader are organically combined by this platform, so that the lifting of the die climbing drives the spreader to lift.
Figure 18 Use simulation diagram of integrated material distributor

Technical features:
① Climbing formwork lifting frame is used as the stress support of the spreader platform.
② Compared with the traditional method, it reduces the labor and material investment in the construction site, avoids the potential safety hazard caused by the reserved hole, ensures the safe and efficient use of the material distributor, and has the advantages of assembly and tooling construction.
③ The distributing machine platform is higher than the climbing formwork platform, which is an independent system and does not affect the construction of the climbing formwork's own working face.
④ The distributing machine platform is flexible and adaptable, and can be applied to various distributing machines.

Because the elevator shaft in the core tube of this project is not provided with a climbing formwork platform and the core tube area is small, which is restricted by the height of tower crane and climbing formwork, the manual spreader is selected for concrete pouring according to the layout technical characteristics of each spreader.

(6) Treatment technology of lagging horizontal structure outside core barrel
As this project adopts the three-dimensional crossing construction operation, the horizontal structure of the outer frame generally lags behind the core tube by 6-8 floors. Generally, the reinforcement of floor slab is treated by embedding, inserting, planting and reserving straight thread sleeves. According to the actual construction requirements and quality standards, the floor reinforcement outside the core tube is embedded in a 30×100 wire box. When the floor is constructed, the floor reinforcement will be exposed by prying the box cover, which can avoid shaving construction, and is convenient and quick.

(7) Climbing formwork treatment technology for thickness change of super high-rise wall
The wall thickness of the outer wall of the core tube of this project changes from the outer side to the inner side with the change of height, and the maximum cross-section change of the wall thickness corresponding to the attachment point of the frame position is 100mm. (When the cross-section change is less than or equal to 50mm, the climbing formwork body can smoothly climb to the next level by adjusting the anti-tilting device of the guide rail (adjusting the supporting leg) without any auxiliary measures. Therefore, the climbing formwork system only needs 50mm wall-attached cushion plate.)

The key points and solutions of variable cross-section climbing of hydraulic climbing formwork in this project are as follows:
1) Change the wall interface, install the upper wall attachment device and pad the variable cross-section base plate.
2) Operate the electronic control button to climb the guide rail. When the guide rail is about to climb into position to the upper wall attachment device, adjust the adjusting leg on the lower frame to make the guide rail tilt inward, and then climb into position.
3) Climb the frame after the guide rail is in place.
4) Complete variable cross-section climbing operation.

5) Variable cross-section treatment of protective steel mesh
   When the cross section of the wall changes, it is only necessary to move the corner protection nets on both sides to the outside to the required position.

6) Treatment of platform plate with variable cross-section and corner position
Due to the shrinkage of the external wall of the structure, the platform plate at the corner should be locally adjusted and cut.

7. **Installation and removal of climbing formwork**

7.1. **Climbing formwork installation and construction**

(1) Installation of wall embedment and wall attachment devices

According to the structural characteristics of this project, the climbing formwork positions are all arranged on the shear wall. When the climbing formwork for the outer wall of the core tube binds the wall reinforcement, a Φ60 sleeve is embedded in each position on the wall. After concrete pouring and molding, check whether the embedded deviation of the climbing formwork position is within 5 mm, check whether the concrete strength is above 15MPa, and install the wall attachment device at the embedded position after checking that it meets the requirements.

(2) Climbing module assembly and hoisting

1) Pre-assemble the lower frame and hanger on the ground
2) Integral hoisting of the lower frame
3) The ground assembling formwork support frame
4) Hoisting formwork support frame
5) Assembling the upper frame on the ground
6) Hoisting the upper frame
7) Lay the platform perfectly
8) Install hydraulic climbing system
9) Ground assembly of steel mesh
10) Steel mesh hoisting in place
11) Closure of corner protection net
12) After the steel binding is finished, install the aluminum mold.

7.2. **Removal of climbing formwork**

According to the characteristics of this project, the dismantling work strictly follows the dismantling sequence of protective net → upper frame → formwork support system → lower frame. The principle of dismantling the lower frame starts from the north and completes the dismantling clockwise. Under the condition of ensuring the safety of personnel and equipment, some positions can be dismantled alternately. First, remove the mesh and the upper frame, and the removal sequence is the frame number sequence.

(1) Dismantle all aluminum formwork towed by the frame body

(2) Clean up the sundries in the frame body, remove the scaffold board and skirting board on the frame body, divide the frame body into independent units with 2-4 seats, and release the connection between the two independent units.

(3) Dismantle the steel plate net of hydraulic climbing formwork of external wall until it disintegrates on the ground.

(4) Hang the upper frame with tower crane, remove the connecting bolts, and lift the upper frame away from the lower frame to the ground for decomposition. When removing the upper frame, it must be ensured that each position has wire ropes, and the frame with large span needs to be leveled by manual hoist before being removed as a whole. Tower crane or truck crane shall cooperate during disintegration.

(5) Hang the shuttering system with tower crane, pull out the pin shafts on the adjusting legs and height adjusting bolts, and lift the shuttering system away from the lower frame to the ground for decomposition.

(6) Slowly dismantle the guide rail and lift it away from the working face with tower crane.

(7) Dismantle the hydraulic electric control system and the lower attached wall seat of climbing formwork and lift it away from the working face.
(8) Hang the lower frame and hanger system to the ground as a whole for decomposition.

8. Summary
According to the structural characteristics and construction difficulties of this project, this paper analyzes the construction technology of super high-rise hydraulic climbing formwork under aluminum formwork system, and determines that the reasonable application of aluminum formwork system and hydraulic climbing formwork can give full play to the advantages of convenient operation, high construction safety, flexible disassembly and assembly of aluminum formwork, high rigidity, large plate surface, few flat seams, high precision, smooth concrete surface and low dependence on machinery during construction.

The use of three-dimensional cross construction, quick-release system and hydraulic climbing formwork construction technology for internal and external walls can effectively reduce safety risks, reduce mutual interference and restriction between working procedures, reduce labor and material costs and maintenance costs, expand application scope, greatly improve construction efficiency, and have high recovery value of aluminum formwork and climbing formwork.

The construction technology of super high-rise hydraulic climbing formwork under aluminum formwork system is not only to solve the construction problems of this project, but also to inspire the majority of construction workers to actively explore the effective means of applying hydraulic climbing formwork construction technology and aluminum formwork system, so as to bring its effectiveness into full play, which is of great significance to promote the development of super high-rise construction industry.

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