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Research on Auxiliary Installation Construction Technology for Limiting Devices of Vertical Components in Prefabricated Buildings

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ABSTRACT: A construction technology for auxiliary installation of limiting devices for vertical components in prefabricated buildings is proposed. This technology utilizes customized fixing plates to secure the steel reinforcement, preventing it from bending or shifting during concrete pouring. Limiting templates are employed to ensure rapid and precise docking of the pre-embedded steel reinforcement and sleeves of prefabricated vertical components, thereby reducing installation errors. Adjustable braces and other means are used to adjust the verticality, elevation, and horizontal position of the vertical components, enabling a more meticulous construction process. High-performance grouting material is used to reliably connect the lower steel reinforcement with the upper components. After curing, temporary supports are removed, which enhances the installation efficiency of vertical components and reduces the onsite working time of workers. Consequently, the shortened construction duration leads to decreased labor costs for installation personnel and management staff, as well as reduced operational costs for machinery and equipment.

Keywords - prefabricated buildings; prefabricated vertical components; limiting device; auxiliary installation; construction technology

I. INTRODUCTION

Prefabricated concrete structures are an inevitable requirement for the modern industrialization of the construction industry. Due to their low pollution, high degree of industrialization, energy efficiency, and environmental friendliness, they have been vigorously promoted in recent years. However, the further promotion and application of prefabricated concrete structures face bottlenecks. Currently, the overall professional quality of construction personnel is not high, and there is a lack of accumulated technical experience and summaries related to prefabricated concrete structures. There is also a lack of comprehensive and accurate understanding and mastery of the technological processes and key operation points of prefabricated structures, resulting in low construction efficiency, large construction errors, and even construction mistakes. Therefore, it is necessary to conduct research based on traditional prefabricated structure construction processes.

Cai F proposed a lap splice connection using grouted sleeves with APC (Assembled Precast Concrete) connections, which boasts high fault tolerance, convenient construction, dense grouting, and low cost. It also enables full prefabrication of vertical components[1]. Ren H analyzed the construction process of shear wall structures in prefabricated residential buildings, including the process for vertical components[2]. Quansheng H conducted experimental research on the direct shear mechanical properties of vertical joints in prefabricated multi-story concrete shear wall structures using dry connections. This connection method employs high-strength bolts and has no exposed steel reinforcement at the edges of prefabricated components, featuring high production and construction efficiency[3]. Chuan W designed the layout of reinforcement at the joints between prefabricated components and cast-in-situ strips, making local adjustments to the reinforcement of components to meet the structural stress requirements and ensure the connection between various components and cast-in-situ strip reinforcement, thereby guaranteeing the safety and stability of the entire structure[4]. Mai D analyzed the lifting techniques and key points and requirements for installation quality control of vertical prefabricated columns in different construction environments. The study also examined precautions for the transportation and stacking of vertical prefabricated columns, as well as the inspection of grouting saturation for finished vertical prefabricated columns[5].

This paper focuses on the alignment and adjustment of vertical components, developing an auxiliary installation construction technology for limiting devices for vertical components in prefabricated buildings`. The goal is to improve construction efficiency and ensure high construction quality.

II. PROCESS PRINCIPLES AND CHARACTERISTICS

The auxiliary installation construction technology for limiting devices of vertical components in prefabricated buildings is a set of installation techniques specifically designed for prefabricated concrete vertical components of prefabricated structures. These components are prefabricated in factories, transported to the site after acceptance, and then quickly assembled. The technical principles of this technology are as follows:

Modular lifting beams are used to lift prefabricated shear walls of various sizes. Customized fixing plates are utilized to secure the steel reinforcement, preventing it from bending or shifting during the pouring process. Limiting templates are employed to ensure rapid and precise docking and positioning of the embedded steel reinforcement and sleeves of the prefabricated vertical components. Construction measurement methods from steel structure projects are introduced, utilizing adjustable braces to adjust the verticality, elevation, and horizontal position of the vertical components. High-performance grouting material is used to reliably connect the lower steel reinforcement with the upper components. Temporary supports are removed after curing is completed. This technology has achieved standardization, normalization, and refinement in the rapid installation process of vertical components in prefabricated concrete structures, significantly improving construction efficiency, reducing installation errors, and enhancing construction quality.

By adopting measures for precise positioning of steel reinforcement and alignment installation of prefabricated wall panels and column components, this technology summarizes methods for fine-tuning and correcting elevation, horizontal position, and verticality. Innovatively, it introduces some measurement techniques from steel structure construction, making the fine-tuning and positioning of components faster and more accurate. This has resulted in a complete set of positioning and installation construction techniques, solving the challenge of precise positioning and installation of vertical components and ensuring easier control of construction quality. Special positioning templates are used for the steel reinforcement, and modular lifting beams are employed to lift prefabricated shear walls of different sizes. Limiting templates are used during the positioning of vertical components to improve alignment efficiency, achieving rapid and accurate installation and positioning, enhancing construction efficiency, and saving construction time. This technology systematically summarizes and improves the management and operation of the entire construction process of prefabricated vertical components, including site layout, lifting process, positioning adjustment, grouting construction, etc. It has formed a complete and detailed construction process, making the construction process more systematic and standardized. This leverages the advantages of prefabricated structures, such as high construction efficiency and easy quality control, and improves construction management levels.

III. AUXILIARY INSTALLATION CONSTRUCTION TECHNOLOGY FOR LIMITING DEVICES OF VERTICAL COMPONENTS IN PREFABRICATED BUILDINGS

3.1 Incoming inspection and acceptance

Upon arrival of the components, a full inspection shall be conducted on their component numbers, production dates, and quality acceptance marks. Inspections on the concrete strength, dimensions, and flatness of the prefabricated components shall also be carried out according to quality control measures. The specifications, positions, and quantities of embedded parts, dowels, sleeves, reserved holes, and temporary braces on the prefabricated components shall comply with the requirements of standard drawings or designs. The sleeves and grouting materials shall also meet quality control standards. Each grouting connection sleeve hole shall be inspected to ensure no foreign objects are inside, and each grouting and discharging hole (which can be checked by blowing in compressed air) shall be inspected to ensure the pipelines are unobstructed.

3.2 Acceptance and treatment of existing structures

Before lifting, the construction quality of the completed cast-in-situ or prefabricated structures shall be inspected and verified as required. Construction shall commence only after the completed structures have been inspected and qualified. All acceptance items shall meet the design requirements, mainly including: the concrete strength of the cast-in-situ structures; the position of axes, elevations, sections, and the locations of embedded parts and reserved reinforcement.

According to the specific dimensions and the central positions of connecting reinforcement of each shear wall and column, corresponding fixing plates shall be fabricated. Using machining methods, reinforcement position detection holes (with a diameter of the maximum outer diameter of the reinforcement +3mm) and positioning reference sidelines for the outer contours of walls and columns shall be processed on the fixing plates. The deviation between the reinforcement detection holes and the theoretical positions shall not exceed

±1mm; the reference line for the column contour shall be +2mm to +3mm compared to the theoretical position. The fixing plates are used to secure the reinforcement to prevent disturbance to the vertical reinforcement during concrete pouring. The upper and lower sides of the fixing plates are fixed with sleeves, and the embedded reinforcement is enclosed with plastic tubes, with a 20mm gap at the bottom wrapped with adhesive tape. After the concrete pouring is completed, the adhesive tape and sleeves are removed, and the fixing plates are then taken off.

3.3 Surveying and setting out

3.3.1 Horizontal control surveying and setting out

Determine the optimal control lines based on the engineering structure layout, and then select the most reasonable locations for control points on these lines, using a theodolite to mark the positions of the control points. The control points should be positioned to avoid vertical components and other adverse factors that could affect line-of-sight visibility. Ensure that there are good visibility conditions between the points. There should be no fewer than four vertical control points for the axial lines on each floor.

Corresponding to the completed floor control points, reserve holes with a diameter of 150mm at corresponding positions on the new floor slabs, penetrating both the prefabricated and poured sections. Use a vertical alignment instrument to project laser beams upward from the completed floor control points, and use a laser receiver target on the new floor to receive the beams. Rotate the vertical alignment instrument 360° to check for eccentricity. If the error diameter is less than 10mm, take the center as the new floor control point and further survey and set out this floor. Based on the control points, use a theodolite to set out the control lines, and accordingly set out the component boundary lines, measurement-related embedded parts, and the positions of limiting templates.

3.3.2 Horizontal Positioning of Limiting Templates

Combined limiting templates are used for the alignment of middle columns, which need to be fixed with bolts at three positions not on the same straight line to prevent horizontal movement of the columns. For corner columns, fix all three bolts of the base fixing plate of each limiting template to prevent rotation and horizontal displacement. For wall limiting templates, two individual alignment templates are used, fixed at both ends of the wall. For interior walls, place them on both sides of the wall thickness, and for exterior walls, place them on one side. Fix all three bolts of the base fixing plate to prevent rotation and horizontal displacement.

3.3.3 Elevation control surveying and setting out

Each floor should have no fewer than one elevation control point for surveying and setting out. For the ground floor and floors with visibility, use a total station instrument, place a vertical rod of known height at the survey station on the floor, place a small prism on top of the rod, and use the principle of triangular height measurement to measure the elevation of the floor. For floors where upward surveying and setting out cannot be done using a total station instrument to measure the floor elevation, use a total station instrument and a tape measure to transfer the benchmark to the tower crane. Transfer the elevation benchmark to the survey station on the construction working level using a total station instrument or level gauge.

3.4 Hoisting of prefabricated elements

On site, the lifting position of components, the stacking location within the construction floors, and the movement range of the tower crane trolley should be determined based on the lifting parameters of the tower crane equipment. Prior to lifting, lifting gear should be installed, with lifting points set at multiple locations where the distance from two points on the precast component to its center of gravity is equal or where the corresponding resultant force point is the center of gravity, ensuring that there are at least two lifting points. For the lifting of precast columns, as shown in Figure 1, hooks should be selected based on the lifting points of the precast components. When hooks are used on both sides, ensure that the hook points are equidistant from the center. During lifting, it is sufficient to ensure that the steel wire ropes remain in a vertical state.

Fig. 1 Hoisting of precast columns

3.5 Installation positioning

When lifting the component to a position 30 to 50 centimeters above the installation site, identify the orientation of the component and align it with the limiting template before lowering it into place. For the upper braces of precast columns and wall panels, the distance from the support points to the bottom should not be less than two-thirds of their height and should not be less than half of their height. Each precast column should be supported by no fewer than two diagonal braces, and each precast wall should be supported by no fewer than two long diagonal braces and two adjustable short diagonal braces. The horizontal angle between the diagonal braces and the floor should be greater than 60 degrees. The positioning of the precast column is illustrated in Figure 2.

Fig. 2 Positioning of precast columns

3.5.1 Fine-tuning and correction of verticality

After completing the horizontal positioning and adjustment of the component, use diagonal braces and adjustment rods to adjust the verticality of the component. For shear walls, long diagonal braces with adjustment rods are used for fine-tuning to adjust the verticality. A theodolite is used for verticality adjustment. The method involves sighting the center point at the top of the component in two mutually perpendicular directions using a theodolite, and then comparing the difference between the projected point of this center point and the center point on the corresponding column side at the bottom of the component. This difference represents the deviation in verticality of the component in this direction, and the deviation should not exceed 5mm; if it does, adjustments are required. If the line of sight is obstructed or it is inconvenient to set up a theodolite due to narrow space, a total station instrument with a small prism can be used for direct observation, and the three-dimensional coordinates of the top of the component are controlled by the total station instrument. That is, after the component is lifted into place, the total station instrument is set up on a plane with a wide view for observation. During the column correction process, place the small prism on the top corners of the column or wall and measure each point one by one until the designed coordinate values match the measured coordinates by the instrument.

3.5.2 Fine-tuning and correction of column top elevation

Set up a total station instrument at the survey station on the floor and place a small prism on the top of the installed component. Measure the elevation of the top of the component using the principle of triangular height measurement. Determine the position of the top of the component in combination with its length, identify the deviation at the top, and decide whether to adjust based on the measured deviation value. If the elevation deviation is≤5mm, it is only recorded without adjustment; if it exceeds 5mm, adjustments are made by adding or removing shims.

3.5.2 Fine-tuning and correction of horizontal position

Correct the horizontal position of columns, walls, and the horizontal position in the direction perpendicular to vertical wall panels. Make repeated fine adjustments until the elevation, horizontal position, and verticality all meet the error requirements. The positioning and adjustment of vertical components are illustrated in Figure 3.

Fig. 3 Positioning and adjustment of vertical components

3.6 Grouting and Filling

In the early stage, the grouting connection cavity at the bottom of the prefabricated component is sealed with sealing strips or high-strength cement-based grouting material to prevent foreign objects from entering the cavity before grouting. In the later stage, grouting material is used to seal the edges around the base of the wall and column, forming a sealed grouting cavity to ensure effective sealing under maximum grouting pressure. The grouting material should be prepared according to the instructions. The grouting material should be mixed evenly for a period not less than 3 minutes; after mixing, it should be allowed to stand for 2 minutes to eliminate air bubbles. The time from mixing the grouting material to completion of grouting should not exceed 30 minutes. During winter construction, the grouting material should be mixed with warm water, and the temperature of the mixed grouting material should not be lower than 5°C and not higher than 35°C. After grouting, measures should be taken to maintain the temperature of the connection for at least 7 days.

The grouting of shear walls should be carried out in sections. When using an electric grouting pump, the typical length of a single section does not exceed 1m. After confirming feasibility through physical grouting tests, the length can be extended, but it should not exceed 3m. The width of the partitioning wall should be no less than 2cm, and to prevent blocking the sleeve orifice, it should be positioned no less than 4cm away from the outer edge of the connecting steel bars. During partitioning, templates must be lined on both sides, and the mixed sealing material should be filled into the templates to ensure a dense bond with the surfaces of the upper and lower components. Then, the templates should be removed, and marks should be made at the corresponding positions on the components after partitioning.

IV. CONCLUSIONS

The construction technology for positioning and installation of vertical components with auxiliary limiting devices in prefabricated buildings proposes the use of customized limiting templates to facilitate alignment and reduce damage to the lower steel bars during lifting of prefabricated components. It summarizes the traditional methods for fine-tuning and correction of elevation, horizontal position, and verticality of vertically loaded components and improves some measurement methods used in construction, making the fine-tuning and positioning of components faster, more accurate, and more versatile. It solves the difficulties of low installation efficiency and difficult quality control of prefabricated concrete vertical components, making the construction process more systematic and standardized. It improves construction efficiency, makes construction quality easier to guarantee, promotes construction management levels, and drives industry progress.

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