Research on Construction Technology of Grouted Sleeve Connection Reinforced with Rectangular Spiral Hoop at the Edge Components of Prefabricated Buildings

Hu Zhencheng, Wang Bizhen, Yu Nengcun, Xie Yuzhi

***Abstract*— A construction technique for grouted sleeve connection reinforced with rectangular spiral hoops at the edge components of prefabricated buildings is proposed, which replaces the edge component hoops with welded closed hoops or spiral hoops. The vertical connections of shear walls employ grouted sleeve connections, and the horizontal reinforcement within the vertical reinforcement overlap zone at the bottom of the wall is strengthened. The length of the vertical connecting reinforcement is significantly shorter than that of the reinforcement used in sleeve connections. The horizontal distribution reinforcement of the shear walls should be fully anchored within the edge components and overlapped outside them. The overlapping can be achieved through welding or direct overlapping and should meet the corresponding length requirements. While ensuring the structural safety and reliability, the lengths of the bellows for seams and the grouted anchor reinforcement are shortened, making the installation quicker and the quality more reliable.**

***Index Terms*— prefabricated buildings; building edge component; rectangular spiral hoop; grouted sleeve connection; construction technique.**

I. INTRODUCTION

Prefabricated concrete structures, as an emerging construction method, have gradually become a significant development direction in the construction industry due to their advantages such as high efficiency, low energy consumption, and environmental protection. In prefabricated concrete structures, connection joints are the crucial links between prefabricated components, directly determining the overall performance and safety of the building. Consequently, scholars have conducted extensive research on the connection joints of prefabricated concrete structures.

Bompa et al. analyzed the main performance characteristics and technical parameters between various mechanical crimping techniques for steel sleeves and grouted sleeve connections. Static and cyclic loading tests were performed, yielding comparison results in terms of yield strength, ultimate strength, ductility, and dimensions. This provided theoretical guidance for using sleeve connections with different concrete and steel reinforcement[1-2]. MA W et al. proposed fully prefabricated shear wall specimens with horizontal joints using high-strength bolts and connecting steel frames as connectors[3]. Nzabonimpa introduced a novel dry beam-column joint for prefabricated concrete frame structures. Based on experimental data and finite element analysis, it was concluded that the reliability of this joint connection is comparable to traditional cast-in-situ structures[4]. Zhu Z.F. et al. demonstrated that setting shear reinforcement or steel sections and providing groove-shaped post-cast strips can effectively enhance the shear capacity of the connection area[5].

Prefabricated concrete structures utilize standardized steel formwork, placing high demands on the processing quality of closed spiral hoops. In this paper, combining the advancement and application of grouted sleeve connection technology in prefabricated structures, a construction technique for strengthening grouted sleeve connections with rectangular spiral hoops in the edge components of prefabricated buildings is developed. This technique can overcome the shortcomings of existing single-loop hoops, reinforce the edge components, break through the limitations of prefabricated structural systems, and facilitate the promotion and use of prefabricated structural systems in high-rise buildings.

II. PROCESS PRINCIPLES AND CHARACTERISTICS

The construction technique for strengthening grouted sleeve connections with rectangular spiral hoops in the edge components of prefabricated buildings replaces the conventional hoops in edge components with welded closed hoops or spiral hoops. The hoops are densified to a spacing of 50mm at the ends or corners of shear walls and to a spacing of 100mm near the middle of the wall limbs. The diameter of the hoops is determined by the design hoop diameter, but the hoop ratio requirements must also be checked. The range of reinforced and constrained concrete includes: for the strengthened areas at the bottom of shear walls and the layer above, the hoops should be densified along the full height of the wall; from the second layer above the strengthened areas at the bottom of the shear wall, the hoops should be densified within a range of the grouted sleeve reinforcement overlap height plus 100mm. The vertical reinforcement of the cast-in-situ connection strip can be lapped, welded, or mechanically connected, and the joint surface should be roughened or provided with tooth grooves. The horizontal distribution reinforcement of the shear wall should be fully anchored within the edge components and overlapped outside them. The overlapping can be achieved through welding or direct overlapping and should meet the corresponding overlap length requirements. The horizontal distribution reinforcement within the lap range of the bottom reinforcement of the shear wall should be strengthened, with the horizontal distribution reinforcement enhanced from Φ8@200 to Φ8@100.

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This construction technique adopts standardized reinforcement, ensuring high processing quality and effectively accelerating the construction progress and shortening the construction period. While ensuring structural safety and reliability, the lengths of the bellows for seams and the grouted anchor reinforcement are shortened, making the installation quicker and the quality more reliable. The vertical connections of shear walls employ grouted sleeve connections, and the horizontal reinforcement within the vertical reinforcement overlap zone at the bottom of the wall is strengthened. The length of the vertical connecting reinforcement is significantly shorter than that of the reinforcement used in sleeve connections, which can significantly reduce construction costs.

III. Key Technologies

3.1 Process Flow

Place the hoop material on a rotating support, cut the binding steel strip, straighten the reinforcement for easy traction to the processing system. Perform lofting according to the design requirements of the drawings, bind the vertical reinforcement framework, and process the templates. Install the templates on the rotating rod, insert the vertical reinforcement framework, and wedge the mold system tightly. Install the processing system on the support system and first test whether the rotation of the processing system is normal. Tract the hoop wire to the processing system, fix it at one end of the reinforcement framework, turn the rotating handle, and start spiral winding at the spacing required by the design. After winding the closed spiral rectangular hoop, remove the processing system and mold system, knock out the square wood, dismantle the templates one by one, place the reinforcement framework wrapped with the closed spiral hoop aside, and reinstall the mold and reinforcement framework.

Process Flow: Construction Design Optimization → Positioning and Setting Out → Lifting and Supporting → Grouting → Installation Engineering → Reinforcement Binding→Formwork Installation →Concrete Pouring.

3.2 Key Reinforcement Technology for Edge Components of Shear Walls

Replace the conventional hoop with a welded closed hoop, originally having a 135°hook, and adopt an interlaced overlapping form for the hoops, which not only enhances the confinement of concrete but also constrains the grouted anchor bellows, forming a structural method that produces confined grouted anchor connections for the vertical reinforcement of edge components. The hoops of edge components are strengthened compared to cast-in-situ structures, further enhancing the confinement of concrete and increasing the bearing capacity of prefabricated shear walls. The hoops of the confined edge components are set at a spacing of 50mm throughout their height, and the hoops of the structural edge components are set at a spacing of 50mm within the height of the grouted anchor overlap zone.

3.3 Key Reinforcement Technology for the Body of Shear Walls

The horizontal reinforcement in the body of shear walls is densified within the height range of the grouted anchor overlap zone, with a spacing not exceeding 150mm. The tie reinforcement is densified from Φ6@600×600 to Φ6@400×400 to enhance the shear capacity of the connection zone. Under the premise of meeting specifications, increasing the diameter and spacing of vertical reinforcement and reducing the number of connections facilitate on-site construction and can effectively ensure the quality of assembly for upper and lower walls at the site.

3.4 Technology for Enhancing the Integrity of Prefabricated Shear Walls

A cast-in-situ connecting strip is set between the body of the shear wall and the edge components. A horizontal cast-in-situ strip is provided at the floor level of the shear wall, with at least 2Φ12 full-length reinforcement bars installed within it. A cast-in-situ ring beam is set at the roof level and overlapped with the coupling beam or frame beam. Keyways are provided within the grooves at the bottom of the prefabricated wall body and on the side of the wall body adjacent to the cast-in-situ connecting strip.

3.5 Lifting and Supporting

3.5.1 Lifting of Vertical Components

The lifting of vertical components should adopt the operating mode of slow lifting, fast rising, and gentle lowering. Before positioning the vertical components, shim plates of different thicknesses ranging from 1 to 5mm should be placed on the floor according to the elevation control line to ensure that the installation of vertical components meets the elevation requirements. Trial lifting should be conducted before the actual lifting of vertical components, with the distance between the lifting hook and the limiting device not less than 1m. The lifting speed should be increased gradually and should not exceed the designated levels. When lowering the lifted components, guy ropes should be tied to the base of the components to control their rotation and ensure smooth and stable positioning. When positioning the vertical components, they should be initially placed according to the axis, component edge line, and measurement control line, and then temporarily fixed to the floor using adjustable steel diagonal braces until the vertical components are stable, at which point the lifting hook can be removed.

According to the layout plan and lifting sequence diagram of vertical components, they should be lifted and positioned. Immediately after positioning, diagonal braces should be installed. Each vertical component should be fixed with no less than two diagonal braces installed on the same side. Prefabricated wall panels, prefabricated columns, and other vertical components should be temporarily fixed and connected through diagonal braces to the pre-embedded sleeves on the components and pre-embedded bolts at the bottom. The angle between the diagonal braces and the ground should be 45-60°. The length of the diagonal braces should be adjusted to control the verticality of prefabricated wall panels, prefabricated columns, and other components. The diagonal braces can be removed only after the grouting strength meets the requirements. According to the axis, component edge line, and measurement control line, a 2m-long straightedge and feeler gauge should be used to correct the wall axis and the flatness between vertical components to ensure that the wall axis and wall flatness meet the quality requirements, and that the joint seams of the exterior wall rabbet are straight.

3.5.2 Lifting of Horizontal Components

The lifting of horizontal components should also adopt the operating mode of slow lifting, fast rising, and gentle lowering. When lifting horizontal components, the position and number of lifting points should be determined according to the width and span of the components, ensuring that the force is evenly distributed among all lifting points. For prefabricated composite slabs, steel beam lifting with multiple points can be used. When lifting horizontal components, composite beams should be lifted first, followed by composite slabs, air-conditioning plates, staircases, and other components. Before lifting, the debris and laitance on the connection parts should be cleaned. According to the elevation control line, the support elevation of the horizontal components should be checked, and the deviated parts should be cut, chiseled, or repaired to meet the installation requirements. Two layers of support should be set up. According to the layout plan of temporary supports, the positions of temporary support points should be marked on the floor with ink lines to ensure that the upper and lower temporary supports are on the same vertical line. During lifting, the horizontal components should first be lifted about 500mm above the ground to check for any deflection or jamming of the lifting hook and to ensure even force distribution among all lifting points. Then, the hook should be gradually raised until the horizontal components are about 1000mm above the installation position. After stabilizing the horizontal components manually, they should be slowly lowered into position. During positioning, it should be ensured that the length of the support for the horizontal components meets the design requirements.

3.5.2 Lifting of Horizontal Components

Temporary supports should be installed immediately when the horizontal components are positioned. According to the elevation control line, the height of the temporary supports should be adjusted to control the elevation of the horizontal components. The distance between the temporary supports and the supports of the horizontal components should not exceed 500mm, and the spacing of the temporary supports along the length of the horizontal components should not exceed 2000mm. For composite slabs with a span of 4000mm or more, temporary supports should be added in the middle of the slab to create an arch, with the arch height not exceeding 3‰of the slab span. The temporary supports for composite slabs should be installed along the edge of the slab in the direction of force, so that the upper pad of the temporary supports is located in the middle of the joint between two composite slabs, ensuring the flatness between the bottom joints of the composite slabs.

3.6 Grouting

Before grouting, a comprehensive inspection should be conducted to ensure that the grouting passages and vent holes are unobstructed. The upper and lower connections of vertical components, horizontal connections, and the connections between vertical components and floors should be thoroughly cleaned. The surfaces should be fully watered and moistened 24 hours before grouting and remain damp without ponding until grouting. Before grouting, a 50 × 100mm wooden formwork should be used to support the horizontal and vertical joints, with the wooden formwork fixed using opposed pull screws. The pre-drilled holes with a diameter of 50mm should be reserved in the prefabricated wallboard for the screws to pass through. The contact areas between the wooden formwork and the ground, as well as the walls, should be filled with 20mm thick sponge strips to prevent grout leakage.

Grouting materials should be prepared strictly according to product requirements. A quantitative amount of water should be added to the mixing tank first, followed by the dry materials. Mix thoroughly using a handheld electric mixer for no less than 3 minutes from the start of material addition to the end of mixing. During mixing, the mixing blades should not be lifted above the grout surface to avoid incorporating air. The mixed grouting material should be used within 30 minutes. The grouting sequence should start from the lower passages and then proceed to the upper passages. The grouting process should be conducted slowly and uniformly without interruption, ensuring smooth passages. Once grout emerges from the upper end of the passage, the grouting hole should be sealed. Immediately after grouting, a vibrating rod should be used to vibrate all the grouting material within the completed passages. Secondary grouting should be performed for any unsaturated settlement of the grout after vibration. For grouting of mortar anchor nodes, mechanical pressure grouting should be applied to the lowest grouting hole to ensure that the grouting material is fully and densely packed.

3.7 Installation Engineering

Before on-site assembly, the factory prefabrication personnel should conduct a detailed breakdown of the drawings in the processing plant. The precise locations for embedded wires, boxes, cabinets, and sleeves on each platform should be determined, with a unified standard size for embedding. Due to industrialized production, the wire boxes and cabinets within each platform are embedded and molded in one operation during construction. Only the piping connections within the platform are performed on-site, improving work efficiency and reducing the operation time on the construction site. For concealed wiring of electric conduits, marking and positioning should be done according to the drawings within the factory—stabilizing the inner boxes and cabinets within the prefabricated panels — installing pipes within the cast-in-situ layer of the platform—cleaning and threading the pipes.

3.8 Rebar Binding

3.8.1 Rebar Binding for Cast-in-Situ Nodes

After the prefabricated components are hoisted and positioned, bind the rebars for the vertical connection nodes of shear walls, as well as the connection nodes of beams and plates, according to the structural design drawings. Before binding the rebars, first correct the positions of the reserved anchor rebars and stirrups, as well as the hook angle of the stirrups. The concealed columns of the vertical connection nodes of shear walls and the load-bearing rebars of shear walls should be overlapped and bound, with the overlap length meeting the specification requirements. The longitudinal load-bearing rebars of composite beams should preferably be welded on one side using helper bars.

3.8.2 Rebar Binding for Floor Plates

Overlap and bind the load-bearing rebars of composite plates with the anchor rebars at the outer wall supports, with the overlap length meeting the specification requirements. At the same time, ensure the effective height of the negative bending moment rebars. After binding the rebars of the composite plates, use rebar limit frames to limit the reserved dowel bars for the vertical load-bearing rebars of shear walls and columns to ensure accurate positioning. At the joints between the prefabricated plates of composite plates, the bottom outer rebars of the prefabricated plates can be bent upwards and anchored into the cast-in-situ concrete of the composite layer. The joint width should not be less than 10mm, and the concrete strength grade of the cast-in-situ layer should not be lower than that of the prefabricated plates.

3.8.3 Rebar Embedding and Correction

After completing the rebar binding, locate and mark the temporary support points of vertical structures and the embedded dowel points of infill walls. Arrange electric welders to perform welding according to the marks and correct the reserved rebars and embedded dowel bars of shear walls. The rebars should be vertical and accurately positioned.

3.9 Formwork Setup

Before installing the node formwork, attach double-sided adhesive sponge strips at the floor where the formwork is set up and at the junction between the formwork and the structural surface. Secure the formwork with M12 opposed pull bolts, with Φ20mm plastic pipes sleeved over the bolts. Node formwork wider than 300mm must use double-row bolts. The spacing between opposed pull bolts should not exceed 600mm, the distance between the upper opposed pull bolt and the top of the formwork should not exceed 400mm, and the distance between the lower opposed pull bolt and the bottom of the formwork should not exceed 200mm.

3.10 Concrete Pouring

Concrete pouring mainly involves pouring for nodes and composite plates. Before pouring concrete, clean the trash inside the formwork and on the composite surface, and remove loose stones and laitance. After cleaning the component surface, thoroughly water and moisten the nodes and composite surfaces 24 hours before concrete pouring, and absorb any ponding one hour before pouring. Use a ZN35 immersion vibrator for vibrating the concrete at the nodes and a ZW7 flat vibrator for vibrating the concrete of composite plates. The concrete should be vibrated to achieve compactness. The composite plates should be covered and watered for curing within 12 hours after concrete pouring. When the average daily temperature is below 5°C, plastic sheeting should be used for curing, with the curing time meeting the specification requirements.

IV. CONCLUSION

4.1 The construction technique for reinforcing grouted anchor connections in prefabricated building edge components employs welded closed stirrups or spiral stirrups to replace the stirrups of the edge components. This method utilizes standardized steel reinforcement, ensuring high processing quality and ease of fabrication and convenience;

4.2 The length of the corrugated pipe at the seams and the length of the grouted anchor steel bars have been effectively shortened, resulting in quick installation and reliable quality;

4.3 The vertical connections of shear walls utilize grouted anchor connections. The horizontal reinforcement within the vertical reinforcement overlap zone at the bottom of the wall is structurally strengthened. The length of the vertical connecting reinforcement is shorter than that of the sleeve-connected reinforcement, leading to lower construction costs;

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