Application of Frame-Shear Wall Structure Construction Technology in Building Engineering

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Keywords: Frame-shear wall; Building construction; Concrete pouring; Formwork system; Construction monitoring

Abstract: This paper focuses on the application of frame-shear wall structure construction technology in building engineering, aiming to address issues such as insufficient stability, improper process sequencing, and difficult quality control during the construction of this structure. By sorting out the core requirements of structural construction and analyzing application principles and strategies in combination with actual construction scenarios, three major principles are summarized: prioritizing structural stability, strictly adhering to construction sequences, and strengthening precision control. Additionally, key strategies are proposed, including optimizing concrete pouring, enhancing formwork stability, and refining construction joint treatment. These aim to provide practical references for frame-shear wall structure construction in building engineering, helping to improve construction quality and structural safety.

1. Introduction

The frame-shear wall structure is a building structural system that combines the advantages of frames and shear walls, consisting of frame columns, beams, and shear walls. The frame bears vertical loads, while the shear wall resists horizontal loads. Together, they balance structural flexibility and lateral displacement resistance. Widely used in mid-to-high-rise buildings, this structure meets the demands for large spatial layouts while ensuring overall building stability and seismic performance, making it one of the common structural forms in modern architecture. In modern building engineering, the frame-shear wall structure is extensively applied in mid-to-high-rise buildings due to its combination of frame flexibility and shear wall lateral force resistance. However, during actual construction, issues such as poor structural stability and insufficient precision in component connections often arise due to non-standard technical applications, affecting the overall performance of the building. To address these pain points, it is necessary to systematically sort out the application principles and strategies of this structural construction, clarifying technical key points at each stage. The following sections will elaborate on the core content of technical application from the research background, providing theoretical and methodological support for subsequent construction practices.

2. Application Principles of Frame-Shear Wall Structure Construction Technology in Building Engineering

2.1 Prioritizing Structural Overall Stability

Load calculations before construction must cover both static and dynamic loads. In addition to accurately calculating static loads such as component self-weight and floor live loads, it is essential to consider the building's seismic design category and wind pressure coefficient based on its location. Structural mechanics software should be used to simulate component force distributions under seismic and wind loads, clarifying the load transfer paths between shear walls and frame columns to avoid local component overloading caused by calculation deviations [1]. As the core load-bearing material, concrete's slump directly impacts pouring quality and structural strength. During construction, the slump should be dynamically adjusted according to the pouring height and

  DOI: 10.25236/icacel.2025.159

component cross-sectional dimensions. For shear wall pouring with a height exceeding 3 m, the slump should be controlled within the range of 180 ± 20 mm. Additionally, an appropriate amount of anti-cracking fibers should be added to the concrete to reduce shrinkage cracks caused by hydration heat, preventing cracks from weakening the overall structural stiffness. Real-time monitoring should be conducted to adjust the construction pace. Stress sensors should be used to monitor stress changes at shear wall and frame joints during pouring. If local stress concentration is detected, measures such as adjusting the pouring sequence or adding temporary supports should be promptly taken to ensure the structure remains in a stable stress state during construction, laying the foundation for subsequent seismic performance compliance.

2.2 Strictly Adhering to Component Construction Sequences

As the primary lateral force-resisting components, shear walls require priority completion of steel bar binding and formwork installation. During steel bar binding, the staggered ratio of vertical steel bar connections should be ≥ 50%, and the spacing between binding nodes for horizontal and vertical steel bars should be ≤ 200 mm. Additionally, dark column steel bars should be added at shear wall corners and edge components to enhance node shear resistance. For formwork installation, a full scaffolding support system should be used, with post spacing determined based on formwork self-weight and concrete lateral pressure, generally ≤ 800 mm. Sealing strips should be used at formwork joints to prevent grout leakage, which could affect component cross-sectional dimensions [2]. After shear wall concrete pouring, curing should be carried out in accordance with specifications for a duration of no less than 14 days. Construction of frame beams and columns can only commence after the strength of companion concrete test cubes reaches 75% of the design value. This is because premature construction of the frame could cause the shear wall to bear loads transferred from the frame before forming sufficient strength, leading to cracking or deformation. Third-party testing agencies should be engaged to conduct rebound tests on shear wall strength, ensuring compliance before proceeding with frame construction. This ensures the gradual formation of structural load-bearing capacity from the perspective of process sequencing, avoiding disruption to the structural force system due to reversed sequences.

2.3 Strengthening Construction Precision Control

During axis alignment, laser line projectors and total stations should be used in combination. First, the building's main control axes should be measured and set on the foundation slab. Then, these should serve as benchmarks for measuring and setting shear wall axes in different zones. Bidirectional verification should be conducted after each alignment to ensure shear wall axis deviations ≤ 3 mm. Protective devices should be installed at axis control points to prevent displacement caused by collisions during construction. Verticality control of frame columns should be implemented in stages. Before pouring, a plumb bob and total station should be used to double-check the verticality of column formwork. During pouring, reverification should be conducted every 500 mm of pouring height. Within 24 hours after pouring, a laser plumb aligner should be used to detect column verticality, ensuring a verticality deviation of ≤ 5 mm per floor. If deviations exceed the limit, timely corrections such as grinding or grouting should be made to prevent cumulative deviations from affecting the overall structural verticality [3]. Control of steel bar cover thickness should be tailored to component types. For shear walls, plastic spacers should be used with a spacing ≤ 600 mm arranged in a quincunx pattern. For frame beams and columns, cement mortar spacers with a strength grade ≥ that of the component concrete should be used. After steel bar binding, a steel bar position detector should be used to check the cover thickness point by point, ensuring it remains within the range of 15–25 mm. This prevents issues such as steel bar corrosion due to insufficient cover or reduced effective cross-sectional dimensions of components due to excessive cover, which could affect structural load-bearing capacity.

3. Application Strategies of Frame-Shear Wall Structure Construction Technology in Building Engineering

3.1 Optimizing Concrete Pouring Processes

The quality of concrete pouring in frame-shear wall structures directly affects the load-bearing performance of components. The process should be optimized from four aspects: pouring preparation, layered control, vibration operation, and post-pouring curing to ensure concrete density and strength compliance. Three preparatory tasks must be completed before pouring: checking the mixing state of concrete transport trucks to ensure the transportation time from the mixing plant to the construction site is ≤ 90 minutes; testing the slump upon arrival and adjusting it to the appropriate range based on component type (180 ± 20 mm for shear walls and 160 ± 20 mm for frame beams and columns); cleaning debris and standing water from component formwork and using a high-pressure air pump to blow dust from formwork joints to prevent debris from affecting the bond between concrete and steel bars [4]; reserving vibration channels with a width ≥ 50 mm in steel bar-dense areas to ensure smooth insertion of vibrators into the component interior. During pouring, strict adherence to layered pouring standards is essential, with each layer thickness ≤ 500 mm. A measuring rod should be used to monitor layer thickness in real time to avoid inadequate vibration due to excessive pouring thickness. Vibration operations should follow the "quick insertion, slow withdrawal" principle, with the moving spacing of immersion vibrators controlled within 400 mm and vibration time lasting 20–30 seconds until concrete surface mortar appears and no further sinking occurs. Vibrators should avoid touching steel bars and formwork to prevent steel bar displacement or formwork damage. For steel bar-dense areas such as shear wall corners and frame joints, a small vibrator with a diameter of 30 mm should be used to ensure dense concrete without voids [5]. Curing should commence immediately after pouring, adopting a film-covering method for a duration of no less than 14 days. Watering should be carried out 3–4 times daily for the first 7 days to keep the concrete surface moist and prevent shrinkage cracks caused by rapid moisture evaporation. Through full-process optimization, the incidence of concrete honeycombing and pitting can be controlled below 0.5%, ensuring component load-bearing performance.

3.2 Strengthening Formwork System Stability

The formwork system is crucial for shaping frame-shear wall structure components. Stability should be enhanced from four aspects: formwork selection, support system construction, reinforcement measures implementation, and acceptance testing to avoid formwork displacement or grout leakage during pouring. Formwork selection should be based on component characteristics. Steel-wood composite formwork is preferred for shear walls and frame columns, with a 18 mm thick film-faced plywood panel and a combination of 50 × 100 mm timber and Φ48 × 3.5 mm steel pipe back ribs. The steel-wood formwork should have a flexural strength ≥ 15 MPa and shear strength ≥ 1.5 MPa, capable of withstanding lateral pressures generated during concrete pouring (typically 25–30 kN/m²) [6]. Support system construction should follow calculated plans. For shear wall formwork, a full scaffolding support system should be used, with post longitudinal and transverse spacing determined based on calculations, generally ≤ 800 mm. A 50 mm thick wooden pad should be placed at post bases, with a pad length ≥ 2 spans to prevent post sinking. For frame beam formwork support, a double-row scaffolding system should be used, with post spacing ≤ 700 mm and ledger step spacing ≤ 1.5 m. Continuous diagonal bracing should be installed on the outer side of the scaffolding, with a diagonal angle controlled between 45° and 60° to enhance overall support system stability. Reinforcement measures should be tailored to different components. Shear wall formwork should be reinforced with tie bolts, with bolt diameters determined based on concrete lateral pressure calculations, generally Φ14–Φ16 mm, and bolt spacing ≤ 600 mm. Waterstop strips (for underground structures) or plastic spacers (for above-ground structures) should be installed on both sides of the bolts to ensure shear wall thickness compliance. Frame beam side formwork should be reinforced with steel pipe hoops, with hoop spacing ≤ 500 mm. bottom horizontal tubes and top adjusters should be added to beam bottom formwork, with top adjuster extension lengths ≤ 300 mm to prevent beam bottom sinking [7]. After formwork installation, comprehensive acceptance testing should be conducted. A total station should be used to detect formwork axis deviations, with shear wall axis deviations ≤ 3 mm and frame column axis deviations

≤ 5 mm. A 2 m leveling ruler should be used to check formwork surface flatness, with a deviation ≤ 2 mm. Additionally, water pressure tests (for underground components) or air tightness tests (for above-ground components) should be conducted to ensure no grout leakage at formwork joints. Only after passing acceptance can the next process proceed.

3.3 Refining Construction Joint Treatment Processes

Construction joints are weak points in frame-shear wall structures. The treatment process should be refined from four steps: joint reservation, preliminary treatment, new concrete pouring, and post-pouring curing to ensure tight bonding between old and new concrete and avoid leakage or weak force-bearing capacity. Joint reservation should comply with specifications and design requirements. Shear wall construction joints should be reserved 200–300 mm below floor slabs or beams, while frame beam joints should be reserved within the middle third of the span range. The joint section should be made in a rabbet shape or equipped with a waterstop steel plate (for underground structures), with a steel plate thickness ≥ 3 mm and width ≥ 300 mm, welded and fixed to steel bars with tight welds [8]. Preliminary treatment of construction joints should thoroughly remove surface debris and loose concrete. First, a pneumatic pick should be used to chip away surface laitance and loose stones to a depth ≥ 10 mm, exposing fresh concrete aggregates. Then, a high-pressure water jet (pressure ≥ 0.8 MPa) should be used to flush the joint surface until clean water flows out without dust or debris. Finally, a wire brush should be used to polish the joint surface, enhancing the bond between old and new concrete. Treatment should be completed within 24 hours before new concrete pouring to prevent the joint surface from drying out. Before new concrete pouring, a bonding layer should be laid, consisting of stone-free mortar with the same mix proportions as the concrete, with a thickness of 50 mm covering the entire joint section. Upper-layer concrete should be poured within 30 minutes after laying the bonding layer to prevent initial setting of the mortar. During pouring, priority should be given to the joint area, with a small vibrator used to focus on vibrating the concrete within 500 mm of the joint edge for 10–15 seconds longer than ordinary areas to ensure full integration of the mortar and new concrete without air bubbles [9]. After new concrete pouring, enhanced curing should be carried out. The joint area should be covered with geotextile and sprinkled with water for curing, with a curing duration 7 days longer than ordinary areas to ensure synchronous hardening of old and new concrete, forming an integrated force system. After curing, an ultrasonic detector should be used to test the joint bonding quality, with a sound wave propagation speed ≥ 4000 m/s and no significant sound wave attenuation areas, ensuring joint load-bearing capacity and waterproof performance compliance.

4. Conclusion

This study demonstrates that frame-shear wall structure construction should be centered around three major principles: ensuring overall structural stability through load calculations, material control, and force balancing; progressing construction in the sequence of "shear walls first, frames later" to ensure orderly formation of load-bearing capacity; and establishing a millimeter-level precision control system for axis alignment, verticality, and steel bar cover thickness. Strategies such as optimizing concrete pouring processes, strengthening formwork system stability, and refining construction joint treatment can effectively address common issues during construction, improving structural construction quality and safety performance and providing reliable technical references for similar projects.

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