Exploration on the Application of Aluminum Formwork Technology in Housing Building Engineering Construction

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Abstract: This paper discusses the application of aluminum formwork technology in housing building engineering construction from two aspects: process flow and application strategy. It explores the technical points of design and processing, on-site assembly, pouring and removal, as well as the implementation logic of optimizing turnover plans, structurally adaptive design, strengthening quality control, and multi-process synergy. It proposes an aluminum formwork cost control method based on full-cycle management and an optimized design path combining architectural structural characteristics. The research aims to prove that aluminum formwork technology, through standardized module design and precise construction control, solves the problems of poor component forming quality and high turnover costs associated with traditional formwork, achieving the effects of improving construction efficiency and ensuring project quality, thereby providing a feasible solution for the technological upgrade of housing building construction.

1. Introduction

With the continuous expansion of housing building engineering scale and the increasing requirements for construction efficiency and quality, traditional wood and steel formwork technologies, due to issues such as low number of reuses, low installation accuracy, and complex later maintenance, are gradually becoming inadequate for modern engineering needs. Aluminum formwork technology, with its advantages of light weight, high stiffness, and recyclability, has become an important direction for breaking through the bottlenecks of traditional formwork technology. However, in practical applications, problems such as unreasonable turnover plans, insufficient design and structural compatibility, inadequate quality control, and poor synergy with other processes still exist, restricting its value realization. Based on this, this paper deeply explores the core process flow and application strategies of aluminum formwork technology, teases out its key implementation paths, which is of great significance for promoting the standardized application of aluminum formwork technology in housing building construction and helping the industry improve quality and efficiency.

2. Aluminum Formwork Technology Process Flow

2.1 Aluminum Formwork Design and Processing

Aluminum formwork design and processing must focus on precise structural adaptation and proceed in stages. First, dismantle component sizes based on architectural structural drawings, specifically marking parameters of standard components like load-bearing walls and floor slabs, as well as morphological details of special-shaped components like bay windows and balconies. Simultaneously, refer to construction quality acceptance specifications to clarify requirements for aluminum formwork stiffness and jointing accuracy. Then, use professional software to complete detailed design, splitting standard components into universal modules and designing dedicated

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connection nodes for special-shaped components to ensure no dimensional deviation after module assembly. During the processing stage, select 6061-T6 aluminum alloy material according to design parameters, produce modules through extrusion molding process, and use CNC machining for key parts like pin holes, controlling hole diameter error within 0.5mm. After processing, check dimensions one by one, and promptly rework modules exceeding tolerances to ensure ex-factory aluminum formwork fully meets design requirements.

2.2 On-site Aluminum Formwork Assembly and Correction

On-site aluminum formwork assembly and correction must follow the principle of "benchmark first, layered assembly, point-by-point verification." First, clean debris from the work surface, snap layout lines for wall axes, edge lines, and elevation control lines. Install positioning rebars according to the lines, with spacing not exceeding 1.5m, to ensure accurate installation benchmarks. Assemble in the order of "wall formwork → beam formwork → slab formwork." Connect wall formwork using pins and clips; check verticality with a straightedge for every 2 panels installed, adjusting immediately if deviation exceeds 2mm. After installing beam and slab formwork, calibrate elevation with a level to ensure consistency with design elevation. After complete assembly, check the stability of the support system: uprights bases must be padded with timber, ledgers must be firmly connected to uprights. Finally, conduct an overall check of formwork joint widths; seal joints exceeding 1mm with sealant to avoid grout leakage during pouring.

2.3 Concrete Pouring and Aluminum Formwork Removal

Concrete pouring and aluminum formwork removal require control over pouring quality and removal timing. Before pouring, sprinkle water to moisten the inner walls of the aluminum formwork and apply a water-based release agent evenly without flowing. Use layered pouring during concrete placement, with each layer thickness not exceeding 500mm. The insertion spacing of vibrators should be controlled within 300mm to avoid surface defects caused by missed or over-vibration [1]. After pouring, cure according to specifications. Aluminum formwork can only be removed when the concrete strength reaches above 75% of the design strength. The removal sequence is: first remove non-load-bearing formwork (e.g., beam side formwork), then remove load-bearing formwork (e.g., wall formwork, slab formwork). Use specialty pry bars for gentle prying during removal; prohibit hard knocking or pounding to avoid deformation of the aluminum formwork. Clean concrete residue from the removed formwork promptly and stack it categorized, preparing for subsequent turnover.

3. Application Strategies of Aluminum Formwork Technology in Housing Building Engineering Construction

3.1 Optimize Aluminum Formwork Turnover Plan to Reduce Costs

Conduct precise calculation of aluminum formwork demand. In the early project stage, based on the overall construction schedule, break down the construction cycle for standard floors of each building. Typically, a standard floor of a shear wall structure takes 7-10 days from aluminum formwork installation to removal; use this to determine the usage cycle for a single building. Then calculate the aluminum formwork quantity required per square meter ($1m^2$) based on component sizes; typically, a standard floor of a shear wall structure requires $2.5m^2$ of aluminum formwork per $1m^2$ of floor area. Reserve a 10% surplus to account for loss/wastage, avoiding delays due to insufficient quantity or idle excess. Establish an efficient circulation and handover mechanism. Create an aluminum formwork turnover tracking sheet to record installation and removal times for each building in real-time. Plan routes based on the principle of "priority circulation for buildings in the same batch." Classify and package aluminum formwork before transportation, marking component numbers and installation locations to reduce on-site sorting time. Use specialty racks for fixing during transport, with rack spacing not exceeding 1.5m, to prevent aluminum formwork deformation, keeping the transportation loss rate below 3% [2]. Upgrade maintenance procedures. Require the use of aluminum alloy-specific wrenches for removing pins during disassembly; prohibit using iron hammers for knocking. During cleaning, first use high-pressure water guns to rinse off concrete residue, then use wire brushes to remove stubborn stains, and finally apply release agent evenly, controlling the thickness between 0.2～0.3mm to ensure smooth concrete demolding. Store by categorizing and stacking according to component type, using 10cm high moisture-proof pads at the bottom and covering with tarpaulins on top. Install ventilation equipment in damp areas to increase the number of formwork turns from the conventional 30 times to over 50 times [3]. Implement dynamic cost control. Monthly statistics on formwork turnover times, maintenance costs, and loss costs. Compare planned vs. actual cost differences. If turnover times are lower than expected, analyze if it's due to idle time caused by process delays and adjust the construction pace promptly. If maintenance costs exceed the budget, consider switching from oil-based to water-based release agents to reduce material costs while ensuring effectiveness, keeping the single-use cost within a 10% fluctuation range of the target value.

3.2 Optimize Aluminum Formwork Design Based on Building Structure

Conduct in-depth analysis of building structural characteristics. During the early design phase, review architectural drawings and categorize into "standard components - special-shaped components - node areas": Record dimensional parameters and repetition frequency for standard components like load-bearing walls and floor slabs (repetition rate often exceeds 80% in residential projects). For special-shaped components like bay windows and AC units, note morphological features and construction difficulties (e.g., bay windows are often L-shaped, requiring consideration of formwork disassembly/assembly convenience). For node areas like beam-column junctions, clarify component connection methods and note the stress conditions during concrete pouring for each component, providing a basis for aluminum formwork stiffness design [4]. Promote modular standardized design. For standard components with repetition rates over 80%, adopt a "fixed-size module + universal connector" model. Design wall formwork modules with standard widths of 600mm, 900mm, and 1200mm, pre-reserving pin holes of 16mm diameter at both ends with 200mm spacing. Use universal connectors to assemble different modules, meeting various bay size requirements. Aim for standardized modules to comprise over 85% of the total aluminum formwork usage, enhancing reuse rate. Handle special-shaped components precisely. Use a "three-segment split" for bay windows, dividing them into independent baseboard, sideboard, and top board modules, connected using 8mm thick custom L-shaped connectors to ensure overall stiffness. Process curved balconies using curved aluminum profiles, replicating the curvature from drawings 1:1 with radius error not exceeding 1mm; weld and polish joints to control surface flatness deviation within 2mm. Design integrated formwork for balcony parapets, assembled simultaneously with wall formwork to reduce later secondary construction [5]. Strengthen design verification for implementation. Import preliminary schemes into BIM software to simulate not only the assembly process but also overlay concrete pouring simulations to analyze formwork stress (e.g., increase rib plate thickness from 5mm to 8mm in the bottom 30cm range of walls where stress concentrates). Invite construction teams to participate in reviews, optimizing from a practical perspective (e.g., split modules heavier than 25kg to under 20kg for easier manual handling), finally forming a design scheme that balances precision and convenience.

3.3 Strengthen Quality Control Measures for Aluminum Formwork Construction

Preparatory stage: Before construction, organize special technical briefings to clarify aluminum formwork installation accuracy requirements for teams: wall verticality deviation not exceeding 3mm, flatness deviation not exceeding 2mm, joint width not exceeding 1mm. Support system erection standards: upright spacing not greater than 1.2m, ledger step distance not greater than 1.8m, kickboard height not exceeding 200mm from the floor. Distribute installation manuals with diagrams of key areas, including connection methods for beam-column nodes. Conduct practical assessments after briefings; only qualified personnel can work, avoiding quality issues caused by non-standard operations [6]. In-process control stage: Aluminum formwork installation follows "benchmark positioning → layered installation → point-by-point verification": First, snap wall axes and edge lines on the slab, install positioning rebars with spacing not exceeding 1.5m to ensure accurate positioning. Install in layers following "wall formwork → beam formwork → slab formwork" order; check verticality with a straightedge for every 3 wall panels installed, adjusting deviations immediately. Use "sponge strip + sealant" for double sealing of joints: embed sponge strips on the inside with length matching the joint, apply 1mm thick sealant on the outside to prevent grout leakage. After erecting the support system, perform pre-loading with sandbags at 1.2 times the design load for not less than 24 hours, observing settlement. Assign dedicated personnel for standing supervision during concrete pouring, controlling wall pouring speed not to exceed 2m/h; stop work and reinforce immediately upon detecting formwork deformation or grout leakage [7]. Post-construction improvement stage: After demolding, organize inspections focusing on component surface flatness, verticality, and presence of honeycombs/pitting. Repair local grout leakage areas not exceeding 0.01m^2 with 1:2.5 cement mortar, curing for 7 days. Grind down formwork bulges with deviations exceeding 5mm to ensure flatness meets standards. Establish a quality ledger recording problem types, corrective measures, responsible persons, and times. Conduct monthly statistical analysis to identify high-frequency issues (e.g., joint leakage) and optimize sponge strip specifications or increase inspection frequency for continuous quality improvement.

3.4 Promote Synergistic Application of Aluminum Formwork with Other Processes

Demand analysis stage: During the early project phase, identify synergy types such as prefabricated construction, fully cast-in-place exterior walls, and plaster-free finishes. Clarify key synergy points: synergy with prefabrication requires ensuring connection accuracy between precast components and cast-in-place structures, with concrete pouring thickness deviation at connection points not exceeding 2mm; synergy with fully cast-in-place exterior walls requires simultaneous completion of structural and insulation layer construction, with bond strength between insulation and structural layers reaching above 0.6; synergy with plaster-free finishes requires wall flatness deviation not exceeding 3mm and verticality deviation not exceeding 2mm to meet direct skimming requirements [8]. Scheme design stage: Develop technical routes for different synergy scenarios: For synergy with prefabricated construction, reserve installation slots in the design, 5mm larger than the component for easy adjustment, and set positioning pins to ensure installation position deviation within 2mm. For synergy with fully cast-in-place exterior walls, adopt an "integrated aluminum formwork + insulation board" design, fixing insulation boards to the inside of the aluminum formwork with specialty connectors spaced no more than 300mm apart, achieving simultaneous structural and insulation layer construction during pouring. For synergy with plaster-free finishes, strictly control aluminum formwork accuracy during installation, use layered vibration during pouring (20-30s duration) to avoid air bubbles, perform local repairs after demolding (area not exceeding 5% of the wall surface), and proceed directly to skimming. On-site implementation stage: Establish a multi-process synergy team, clarifying responsibilities for each process owner. Develop a schedule (e.g., precast component delivery 24h before aluminum formwork installation). Hold weekly synergy meetings to resolve on-site issues like conflicts between components and formwork. After aluminum formwork installation, have the prefabrication team verify acceptability before hoisting components to ensure synergy quality [9]. Effect evaluation stage: After project completion, compare indicators before and after synergy: Synergy with plaster-free finishes shortens wall decoration duration by 15-20 days; synergy with fully cast-in-place exterior walls reduces insulation layer construction cost by about 20 yuan/m^2; synergy with prefabricated construction reduces leakage rate at component connections to below 0.5%.

4. Conclusion

The above research indicates that the effective application of aluminum formwork technology in housing building engineering construction relies on sound process flows and targeted application strategies. The design and processing stage focuses on precise structural adaptation, ensuring module quality through professional software detailing and precision machining. The on-site assembly stage follows the principle of "benchmark first, layered verification," ensuring installation accuracy and support stability. The pouring and removal stage controls quality and timing, reducing component defects and formwork loss. These three form a coherent construction chain. Optimizing the turnover plan can reduce costs through demand calculation and maintenance upgrades. Structurally adaptive design can improve module reuse rate and construction convenience. Strengthening quality control ensures construction quality through full-process closed-loop management. Multi-process synergy further enhances overall construction efficiency.

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