



Application Advantages of Aluminum Formwork and Climbing Scaffold Combined Technology in Residential Buildings

Fang Zhang

China First Highway Engineering Co., Ltd., Beijing 100024, China.

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***Corresponding author:** Fang Zhang, China First Highway Engineering Co., Ltd., Beijing 100024, China.

Abstract

The aluminum formwork and climbing scaffolding combination technology, as an innovative and efficient construction solution, is widely used in high-rise residential buildings. This paper analyzes the core components of this technology, including the organic combination of the aluminum alloy formwork system and the attached lifting scaffolding system. Based on high-strength materials and standardized design, the aluminum alloy formwork features high precision, high rigidity, and corrosion resistance, effectively improving the accuracy and quality of structural construction while reducing costs. The attached lifting scaffolding provides comprehensive protection and synchronous lifting support for high-altitude operations, ensuring construction safety and optimizing the construction process. By analyzing the advantages of the aluminum formwork and climbing scaffolding combination technology, this paper explores its contributions to improving construction efficiency, ensuring construction quality, and optimizing construction management. Finally, considering current technological development trends, this paper proposes future technology upgrade and promotion strategies, providing a reference for technological innovation in the construction industry.

Keywords

Aluminum alloy formwork; Attached climbing scaffold; Combined construction technology; Residential building

1. Introduction

With the increasing demand for large-scale and efficient residential buildings, traditional formwork and scaffolding methods have gradually exposed issues such as long construction periods, high costs, and safety risks, particularly in high-rise residential projects [1]. The combined technology of aluminum alloy formwork and attached climbing scaffolds has gradually become the mainstream method for residential construction due to its high precision, efficiency, and strong safety features. This technology combines the precision advantages of aluminum formwork with the protective and lifting functions of climbing scaffolds, not only improving construction efficiency and optimizing quality control but also enhancing safety management and resource allocation. This paper analyzes the application advantages and development prospects of the aluminum formwork and climbing scaffold combined technology, offering a reference for technological innovation in residential construction.

2. Core Composition of Aluminum Formwork and Climbing Scaffold Combined Technology

The core composition of aluminum formwork and climbing scaffold combined technology includes the integration of the aluminum alloy formwork system and the attached climbing scaffold system. The aluminum alloy formwork

uses high-strength aluminum alloy profiles and standardized connectors, providing high precision, high rigidity, and corrosion resistance. Its smooth surface ensures that errors are controlled within millimeters, guaranteeing accurate concrete structural dimensions and reducing common issues like honeycomb surfaces and misalignment [2]. The lightweight design makes formwork installation and removal more convenient, and it can be reused multiple times, lowering construction costs. Especially in high-rise residential projects, the precision and strength of the aluminum formwork ensure construction quality, while the modular design improves site management efficiency [3].

The attached climbing scaffold system connects to the building's main structure and uses hydraulic or electric systems to achieve synchronized vertical movement [4]. This reduces the space occupation and time required for assembling and disassembling traditional scaffolds. The fully enclosed design effectively prevents falling objects from heights, ensuring the safety of construction workers and providing stable external facade protection. The load-bearing design of the climbing scaffold ensures stability and safety during the vertical movement process and synchronizes well with the aluminum formwork system. This optimizes the workflow, improving construction efficiency and safety management.

3. Application Advantages of Aluminum Formwork and Climbing Scaffold Combined Technology in Residential Buildings

3.1 Advantages of Improving Residential Construction Efficiency

The core advantage of the aluminum formwork and climbing scaffold combination in improving residential construction efficiency lies in the effective collaboration between standardized construction units and mechanized operations. The aluminum alloy formwork, with its factory prefabrication and modular design, enables efficient and precise installation and removal, reducing on-site adjustment time and allowing for repeated use over multiple floors, ensuring a stable construction pace [5]. The new climbing scaffold, driven by hydraulic or electric systems, moves upwards synchronously, overcoming the problems of repetitive assembly and disassembly and space occupation typical of traditional ground-based scaffolds. It enables simultaneous work on facade protection and the main structural construction.

When combined, the system allows the construction team to complete the installation and removal of formwork, concrete pouring, and preparation for facade construction within the same time period, greatly shortening the construction cycle to two-thirds of the originally planned time [6]. This comprehensive technology optimizes the configuration of human, material, and machinery resources at the construction site. Compared to ordinary designs, the lightweight design of the aluminum formwork reduces the difficulty of hoisting and handling, lowering labor consumption while improving mechanical hoisting efficiency. The overall lifting of the climbing scaffold reduces the time needed for disassembling external scaffolds and arranging temporary supports, streamlining the construction process. With a unified construction rhythm and the promotion of multi-process collaborative construction, the system effectively establishes a flow construction mode, optimizing process flow, greatly reducing waiting times and interference between processes, improving overall construction efficiency, and ensuring project schedule control. This approach is particularly suitable for residential projects with many high-rise and standard floors.

3.2 Advantages of Ensuring Construction Quality in Residential Projects

The combination of aluminum formwork and climbing scaffold technology demonstrates significant advantages in ensuring the construction quality of residential projects. The essence of these advantages lies in structural accuracy control and the optimization of the construction environment. By utilizing factory-based processing flows and modular design patterns, the aluminum alloy formwork achieves a surface flatness of ± 1 mm and node connection accuracy controlled within ± 2 mm. This greatly enhances the control over geometric size deviations in shear walls, beams, and slabs, reducing common quality issues such as misalignment of concrete, honeycomb surfaces, and surface cracks. The standardized backing ribs and supporting system can withstand up to 0.9 MPa of concrete lateral pressure during pouring, ensuring that the formwork meets the required shape under construction loads, which in turn improves the surface smoothness and verticality of the structure, providing a reliable foundation for subsequent decorative construction [7].

The attached climbing scaffold, based on its fully enclosed protection and balanced load-bearing design, creates a continuous and stable working space for construction, effectively reducing the impact of wind, rain, and other environmental factors on concrete pouring quality. In practical applications, the climbing scaffold can meet the operational load requirement of 2.0 kN/m^2 and, with the addition of fall protection devices and a synchronized lifting control system, ensures the coordination of facade construction and formwork assembly and disassembly [8]. After

combining the two systems, the construction team can perform the formwork installation in the building while simultaneously preparing the facade protection, using standardized floor-by-floor repetition and real-time measurement verification to control structural dimension deviations within ± 3 mm. Compared to the traditional wood formwork and ground-based scaffolding system, the construction quality is about 20% better, significantly reducing rework rates and enhancing the overall stability and durability of residential project quality.

3.3 Advantages of Optimizing Construction Management in Residential Projects

The combination of aluminum formwork and climbing scaffold technology brings significant advantages to optimizing construction management in residential projects. The primary benefit is in the standardization and refinement of management during the construction phase. The aluminum alloy formwork system's highly detailed, modular, and standardized design requires construction teams to carry out comprehensive layout and planning before construction begins. Using Computer-Aided Design (CAD) and Building Information Modeling (BIM), the dimensions, assembly, and supporting systems of all formwork can be precisely confirmed, reducing quality issues caused by design flaws or construction errors at the source. The time, materials, and labor costs for each construction process can be pre-budgeted, thanks to this refined management, and the construction site can be promptly scheduled according to the plan, avoiding the inefficiencies and uncertainties caused by frequent adjustments and temporary decisions in traditional construction methods.

The attached climbing scaffold system has fixed operational procedures for the lifting process and facade protection tasks, which enable it to be stabilized and lifted according to a predefined schedule. This not only reduces the time spent on the complex assembly and disassembly of traditional scaffolding but also improves the safety and smoothness of facade work. It contributes to achieving a controlled and predictable construction schedule, significantly optimizing project management.

At the construction site, the combination of aluminum formwork and climbing scaffold promotes the optimized allocation of resources and improved safety. Due to the lightweight and high-precision characteristics of aluminum formwork, it greatly reduces the labor burden of manual handling and installation, accelerates the construction speed, and lowers costs related to frequent wood formwork replacements and site occupation. With the support of the climbing scaffold system, high-altitude operations and facade protection are no longer reliant on temporary support systems, eliminating a large portion of the complex assembly and disassembly processes of traditional scaffolding. The time spent on pre-construction preparation and post-construction cleaning is significantly reduced. The application of aluminum formwork and climbing scaffold technology enhances on-site safety and operational standardization. The fully enclosed protection system and synchronized lifting control of the climbing scaffold not only isolate workers from falling objects and harsh weather conditions but also allow real-time monitoring of construction progress and quality.

4. Prospects for the Application of Aluminum Formwork and Climbing Scaffold Combined Technology in Residential Construction

4.1 Technological Upgrades and Innovation Directions

The primary task for the future development of aluminum formwork and climbing scaffold combined technology is to achieve deep integration with intelligent and digital technologies. With the continuous progress of technologies such as Building Information Modeling (BIM), Internet of Things (IoT), and Artificial Intelligence (AI), the application of this combined technology is gradually expanding towards intelligent monitoring and automated construction. BIM technology can be used to manage the entire lifecycle of formwork and climbing scaffold systems, covering design, construction, and demolition phases, ensuring the precision of each step. With IoT sensors, real-time data can be monitored to track the load, lifting status, and deformation dynamics of the aluminum formwork and climbing scaffold system. Any abnormalities can trigger immediate alerts to ensure construction safety and efficiency. On-site, AI will handle data processing and analysis, predicting project progress, material usage, and potential construction hazards based on past data, optimizing scheduling, reducing manual intervention, and improving construction precision and efficiency.

Innovation in aluminum formwork and climbing scaffold technology should also focus on improving material quality and reducing system weight. While aluminum formwork has already shown advantages in strength, durability, and corrosion resistance, future advancements can introduce new lightweight alloys or composite materials to reduce the weight of formwork, alleviating handling and installation difficulties, and enhancing the durability and

environmental sustainability of the system. The climbing scaffold system can also benefit from lightweight and modular design improvements, incorporating higher-strength and fatigue-resistant steel and composite materials to reduce costs and improve structural stability. Optimizing the automated lifting system with intelligent control technology will enhance the smoothness and speed of the lifting process, reducing mechanical failures and operational risks, further increasing construction efficiency.

4.2 Constraints on the Promotion and Application of Combined Technology

The promotion of aluminum formwork and climbing scaffold technology faces several constraints, particularly in terms of cost. While the technology can save materials and labor costs in the long term, the initial investment in purchasing, installing, and maintaining aluminum formwork and attached climbing scaffolds is relatively high. This is especially challenging for small construction projects with limited budgets, where there is considerable financial pressure at the outset. In terms of resources for application, technical training for construction personnel, and adherence to operational standards pose difficulties. To ensure quality, the aluminum formwork and climbing scaffold systems require workers to have advanced technical skills, especially during formwork installation, disassembly, and scaffold operations. If these processes are not carried out correctly, they can lead to quality issues and safety risks. Project owners must invest considerable resources in training and technical support, increasing management costs.

Additionally, many current projects do not align with the demands of this new technology in terms of construction organization and management models. Traditional construction management systems, schedules, and resource allocation methods are often incompatible with the efficient operation of aluminum formwork and climbing scaffold technology, leading to project delays or resource wastage. In some regions, there is a lack of acceptance of new technologies or a weak technical support system, which slows down the application of the combined technology. The slow development of industry standards and norms further hinders its promotion. Overcoming these barriers requires addressing the cost challenge, improving workforce skills, and establishing a sound policy and standardization system, with support from both the government and industry to expand its application.

4.3 Future Development Strategies and Recommendations

The widespread application of aluminum formwork and climbing scaffold technology will advance through a dual development of technology and management. The industry should leverage multi-dimensional support from policies and market incentives to reduce the high initial investment costs of new technologies. The government should actively introduce financial subsidies, tax reductions, and other favorable policies to encourage construction enterprises to adopt this technology, especially in economically weaker regions. The construction industry could establish a dedicated technological innovation fund to assist small construction firms and contractors in purchasing aluminum formwork and climbing scaffold equipment, thereby lowering the technical barriers. This gradual approach will promote technology adoption and enhance industry standards, particularly focusing on safety regulations and quality testing standards for combined aluminum formwork and climbing scaffolds.

Optimizing technical training for construction workers and promoting multidisciplinary collaboration should also be prioritized. Construction companies should periodically train employees in skills related to formwork installation, climbing scaffold operation, and intelligent monitoring systems, ensuring safe and accurate construction practices. With the aid of BIM technology and intelligent management tools, construction processes can be further optimized and visualized. For large-scale residential projects, it may be helpful to form cross-disciplinary teams combining expertise in building design, construction management, and information technology to promote the efficient implementation of aluminum formwork and climbing scaffold technology. This will enhance construction efficiency, quality, and safety, driving comprehensive growth in residential building projects.

5. Conclusion

The application of aluminum formwork and climbing scaffold technology in residential construction significantly enhances construction quality, efficiency, and safety management levels. With its standardized and modular design, coupled with intelligent monitoring and management, this technology provides reliable construction assurance for high-rise residential projects and promotes the industry's development toward greener, industrialized methods. As technology continues to advance and applications expand, aluminum formwork and climbing scaffold combined technology will play an increasingly important role in future residential projects, driving ongoing innovation and improvement in the construction industry.

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