

Research on the Quality Management Strategy and Practice of Building Curtain Wall Construction

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Abstract: Quality management in building curtain wall construction covers both the essence and scope, including material control and process control. It is crucial for safety, longevity, and energy efficiency. Although quality management models are diverse, they have their limitations. The paper also discusses key points such as quality issues, material and process compatibility, and node construction, along with various techniques and management methods to improve quality. It also highlights areas for further research and future directions.

Keywords: Building curtain wall; Construction quality; Quality management

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1. Introduction

As the outer envelope of a building, the construction quality management of building curtain walls is of vital importance. In recent years, with the continuous improvement of relevant policies in the construction industry, such as the “Quality Acceptance Standard for Building Curtain Wall Engineering” issued in 2019, stricter requirements have been put forward for the construction quality of curtain walls. The connotation of curtain wall construction quality management is rich and varied. It not only covers the control of material quality, management of various construction stages, and oversight of participating entities, but also involves the regulation and supervision of new technology applications. The quality objectives encompass multiple aspects, including safety, functionality, and aesthetics. From the perspectives of building safety, service life, and energy conservation and environmental protection, a scientific quality management system is indispensable. At the same time, although there are diverse quality management models currently in use, they have their shortcomings. There are also many quality issues in construction. These problems not only affect the overall performance of the building but may also bring safety hazards and increased maintenance costs. All these factors highlight the necessity of in-depth research and optimization of the construction quality management of building curtain walls.

2. Overview of construction quality management of building curtain wall

2.1. The core concept of curtain wall construction quality management

The quality management of building curtain wall construction is a systematic task to ensure that the quality of curtain wall engineering meets the expected standards. It includes strict control of the quality of curtain wall materials, which directly affects the performance and safety of the curtain wall. For example, the strength of aluminum alloy profiles, the optical properties of glass, and the weather resistance of sealants must all comply with relevant standards ^[1]. Its scope extends to every link of the construction process and all parties involved. The quality objectives clarify the standards that the curtain wall should meet in terms of safety, functionality, and aesthetics. For instance, the wind pressure resistance of the curtain wall must meet the local climatic conditions. Process control covers every stage of construction, from the installation of embedded parts to the installation of panels, with strict quality monitoring measures for each step. The acceptance criteria serve as the basis for inspecting the final engineering quality, including the detection standards for various indicators such as the plumbness, flatness, and sealing performance of the curtain wall. Research has shown that different project stakeholders have varying perspectives on the quality issues of curtain wall construction, which further highlights the importance of systematic quality management.

2.2. The importance of a quality management system

The quality management system for building curtain wall construction is of vital importance. From the perspective of building safety, the curtain wall, as the outer envelope of a building, may pose safety hazards such as detachment under adverse weather conditions or external forces if its quality is not up to standard, endangering human lives and property. Research has shown that selecting the appropriate curtain wall system is a key factor in ensuring building safety and performance, and a scientific quality management system is the foundation for achieving this goal ^[2]. In terms of service life, a scientific quality management system can ensure that materials and construction techniques meet the standards, thereby reducing premature damage to the curtain wall caused by quality issues and extending its lifespan. Regarding energy conservation and environmental protection, good quality management helps in selecting appropriate energy-saving materials and rational design details, which can enhance the curtain wall's thermal insulation, heat insulation, and daylighting performance, reduce the energy consumption of buildings, and achieve the goals of energy saving and environmental protection. Moreover, with the increasing emphasis on sustainable development in the construction industry, the quality management of curtain wall construction also needs to consider the efficiency of resource utilization and waste management during the construction process to minimize environmental impact.

3. Analysis of quality management status of curtain wall construction

3.1. Current quality management model

The compatibility of material properties and construction techniques is of vital importance in curtain wall construction. Research has shown that automated evaluation techniques can better optimize curtain wall design, thereby improving the match between material properties and construction techniques to ensure construction quality ^[3]. The thermal performance of materials needs to be matched with construction techniques to ensure that the curtain wall meets the required insulation and heat insulation effects. For example, different types of insulation materials require specific installation techniques during construction to fully realize their performance. At the same time, the structural strength of materials must also be compatible with construction techniques. Suitable construction techniques can ensure that materials are not damaged during installation, thereby maintaining their structural strength. For instance, the installation technique for glass in glass curtain walls should avoid improper

operations that can cause cracks in the glass, affecting its structural safety. Only when material properties and construction techniques are highly compatible can the construction quality of curtain walls be effectively guaranteed.

3.2. Typical quality problems and causes

The construction of building curtain walls faces many quality issues. Water leakage is one of the common problems, caused by the aging of sealants and improper treatment of joints. Over time, sealants degrade due to environmental factors, leading to water infiltration. If the joints are not properly sealed during construction, this can also cause leakage. Deformation is another issue that cannot be ignored, which may result from an improper structural design that cannot withstand external forces. In some cases, the insufficient design strength of the curtain wall frame leads to deformation under wind loads and other external forces. Material degradation is also an important factor causing quality problems. For example, glass breakage may be due to uneven internal stress or external impact, while the corrosion of metal materials can affect their structural strength and stability, thereby affecting the overall quality of the curtain wall ^[2]. The occurrence of these problems not only affects the normal use of the building but may also bring safety hazards. Therefore, it is necessary to use scientific quality management methods and multi-criteria decision-making models to optimize the selection and construction management of curtain wall systems to reduce the occurrence of quality problems.

4. System of influencing factors of curtain wall construction quality

4.1. Technical influencing factors

4.1.1. Material performance and process adaptability

The compatibility of material properties and construction techniques is of vital importance in curtain wall construction. Studies have shown that automated evaluation techniques can better optimize curtain wall design, thereby improving the match between material properties and construction techniques to ensure construction quality. The thermal performance of materials needs to be matched with construction techniques to ensure that the curtain wall meets the required insulation and heat insulation effects. For example, different types of insulation materials require specific installation techniques during construction to fully realize their performance. At the same time, the structural strength of materials must also be compatible with construction techniques. Suitable construction techniques can ensure that materials are not damaged during installation, thereby maintaining their structural strength. For instance, the installation technique for glass in glass curtain walls should avoid improper operations that can cause cracks in the glass, affecting its structural safety. Moreover, modern technology has also provided new safeguards for curtain wall construction quality. For example, monitoring and analysis methods based on fiber-optic sensing technology have been used for real-time monitoring of curtain wall deformation, which can detect and address potential deformation problems in a timely manner, further enhancing the safety and reliability of curtain walls ^[4]. Only when material properties and construction techniques are highly compatible and combined with advanced technological means can the construction quality of curtain walls be effectively guaranteed.

4.1.2. Node structure reliability

The reliability of node construction in curtain wall construction is of vital importance. The design of connectors directly affects the stability of the curtain wall structure. The material selection and size specifications must comply with mechanical principles and actual engineering needs. Unreasonable design may lead to uneven force distribution and safety hazards. Sealing treatment affects the waterproofing and airtightness of the curtain wall, and

the quality of the sealing material and the rationality of the sealing process are key factors. High-quality sealing materials can effectively prevent the penetration of rainwater and air, while a rational sealing process ensures the durability of the sealing effect. The construction details at the nodes, such as the connection methods and angles of different components, need to be precisely designed and constructed. Any deviation in these details may affect the performance and quality of the entire curtain wall system. Moreover, with the development of building technology, the design, development, and testing of new curtain wall systems, such as building-integrated photovoltaic/thermal (BIPV/T) systems, are continuously advancing. The node construction of these systems needs to consider both electrical and structural performance requirements, further highlighting the importance of node design [5].

4.2. Management influencing factors

4.2.1. Effectiveness of process supervision

The management blind spots in the connection of construction processes and the acceptance of concealed works have a significant impact on the quality of curtain wall construction. Research has shown that the temperature distribution of glass curtain walls in super high-rise buildings poses higher requirements for the quality control of construction processes and concealed works [6]. In terms of the connection of construction processes, a lack of effective communication and coordination between processes can lead to construction delays and poor connections, affecting the overall quality. For example, if the previous process is not completed according to the standard and the subsequent process is forced to proceed, it may cause cumulative errors that endanger the structural safety of the curtain wall. The acceptance of concealed works, due to its own characteristics, is easily overlooked. For example, if problems such as inaccurate installation positions of embedded parts and insecure connections are not detected during acceptance, they cannot be remedied in subsequent construction, directly affecting the stability and durability of the curtain wall. Therefore, strengthening the supervision of these management blind spots is the key to improving the quality of curtain wall construction.

4.2.2. Professional competence

The skill level of construction workers and the quality awareness of management personnel have a significant impact on the quality of curtain wall construction. The professional skills of construction workers cover many aspects, such as their understanding of curtain wall material properties, including the characteristics and applicability of different materials in various environments. For example, large-scale glass curtain walls in high-rise buildings need to have good wind resistance performance. Construction workers must be familiar with the strength and stability of glass materials under wind loads to ensure the safety of the curtain wall [7]. Their installation skills are also crucial. Accurate measurement, cutting, and installation techniques directly affect the overall quality of the curtain wall. At the same time, the familiarity of construction workers with construction standards and regulations determines whether the construction process is compliant. The quality awareness of management personnel affects the working attitude and direction of the entire construction team. They need to have a keen ability to control quality, being able to promptly identify and correct quality issues during construction, and to reasonably arrange construction progress and resources to ensure that the construction process meets quality requirements, thereby ensuring the quality of curtain wall construction. Moreover, with the continuous development of building technology, construction workers and management personnel also need to continuously learn and update their knowledge to meet the challenges brought by new materials, technologies, and construction techniques. Only by improving the professional skills of construction workers and the quality awareness of management personnel can the overall quality of curtain wall construction be effectively enhanced, ensuring the safety and durability of buildings.

5. Quality management optimization strategy and practice path

5.1. Technical control strategy

5.1.1. Intelligent material detection technology

The construction of an automated detection system for curtain wall materials based on spectral analysis and machine vision is key to intelligent material inspection technology. For example, research on a novel glass curtain wall system has shown that its unique thermal characteristics require materials to meet higher performance standards. Spectral analysis technology can accurately identify the chemical composition and physical properties of curtain wall materials to ensure they meet these requirements ^[8]. Machine vision technology can conduct high-precision inspections of material appearance, such as surface defects and dimensional accuracy. By combining these two technologies, a comprehensive and automated inspection of curtain wall materials can be achieved. This system not only improves detection efficiency and reduces human error but also promptly identifies substandard materials, preventing them from entering the construction phase, thereby effectively ensuring the quality of curtain wall construction.

5.1.2. Innovation of construction process standardization

Unitized curtain wall modular installation can improve construction efficiency and quality. Research has shown that for a novel frame-integrated curtain wall, the selection and characterization of materials are key factors in ensuring its performance ^[9]. By breaking down the curtain wall into modules and prefabricating them in the factory, the amount of on-site work can be reduced, while the precision and stability of quality can be improved. Meanwhile, three-dimensional scanning-assisted positioning technology provides precise spatial data for construction. During the installation process, three-dimensional scanning devices are used to obtain the actual position information of the main building structure and the installed curtain wall, which is compared and analyzed with the design model to adjust deviations in a timely manner and ensure the accuracy of the curtain wall installation position. These process improvement solutions help to enhance the standardization level of curtain wall construction, ensure construction quality, and reduce quality problems caused by non-standard processes.

5.2. Management mechanism optimization

5.2.1. PDCA cycle quality control model

The PDCA cycle quality control model covers four stages: Plan, Do, Check, and Act. In the Plan stage, it is necessary to formulate detailed quality objectives, standards, and procedures based on the requirements of building curtain wall construction, and clarify the quality control points in each link. During the Do stage, construction operations are strictly carried out in accordance with the plan to ensure that all processes meet the standards, including material selection and installation techniques. In the Check stage, a comprehensive inspection of the construction process and results is conducted, employing various detection methods such as visual inspection and performance testing to identify quality issues in a timely manner. In the Act stage, the causes of the identified problems are analyzed, improvement measures are developed and fed back to the Plan stage, and subsequent construction is adjusted and optimized. This forms a continuous cycle of quality management, constantly enhancing the quality of building curtain wall construction.

5.2.2. Multi-entity collaborative management platform

Establishing a digital collaboration mechanism that links owners, designers, constructors, and supervisors is key to enhancing the quality management of building curtain wall construction. By creating a unified digital platform, all parties can share construction information in real time, including design drawings, construction progress, and quality inspection reports. Owners can keep abreast of project developments and voice their opinions and

demands; designers can optimize and adjust designs based on actual construction conditions; constructors can strictly follow design requirements and standards, and promptly report issues encountered during construction; and supervisors can effectively oversee the construction process to ensure it meets quality standards. Moreover, the platform should also have data analysis capabilities to analyze various types of data during construction, providing a scientific basis for quality management decisions, thereby achieving comprehensive and dynamic management of the quality of building curtain wall construction.

5.3. Application of information technology

5.3.1. In-depth application of BIM technology

During the construction of building curtain walls, BIM technology can be deeply applied in many aspects. It is crucial to develop a collision detection function module for curtain wall construction. By creating precise 3D models, potential collision issues between the curtain wall structure, the main building structure, and various curtain wall components can be identified in advance. This allows for timely adjustments to the design scheme, avoiding rework and delays during construction. Meanwhile, a dedicated schedule simulation function module can visually simulate the construction progress of the curtain wall. Based on the construction plan, it sets the time nodes and logical relationships for each process, displaying the construction process in a virtual environment and analyzing the rationality of the schedule and potential risks. The construction team can optimize resource allocation and construction sequence accordingly, ensuring that the curtain wall construction progresses as planned and improving construction efficiency and quality.

5.3.2. Real-time monitoring system using Internet of Things

In the construction of building curtain walls, the deployment of an IoT-based real-time monitoring system can optimize quality management. Utilizing a network of stress and strain sensors, dynamic monitoring of the construction process can be achieved. These sensors can accurately detect the stress and strain conditions of the curtain wall structure at various stages of construction and transmit the data in real-time to the monitoring system. The system analyzes and processes the data, and if any anomalies are detected, it can issue timely warnings to alert construction personnel to potential quality issues. This enables the construction team to promptly take measures to adjust construction techniques or reinforce local structures, preventing the accumulation of quality risks. Moreover, by analyzing a large amount of monitoring data, quality patterns during the construction process can be summarized, providing references for subsequent construction and further enhancing the stability and reliability of construction quality.

6. Conclusion

The quality management of building curtain wall construction is of vital importance. In terms of key technical approaches, it covers every link from material selection to construction techniques, ensuring the stability, airtightness, and aesthetics of the curtain wall. Innovations in management include the introduction of advanced information management tools and enhanced collaboration among all parties involved. However, there are some shortcomings in the current research. For instance, in terms of adaptability to complex climates, the long-term impact of different climatic conditions on curtain wall performance has not been fully considered. In terms of lifecycle cost control, there is a lack of effective cost forecasting and optimization strategies. Looking to the future, artificial intelligence algorithms hold broad application prospects in the field of quality prediction. By learning from and analyzing a large amount of construction data, potential quality issues can be predicted in advance, providing strong support for quality control during the construction process and thereby further enhancing the

quality of building curtain wall construction.

Disclosure statement

The author declares no conflict of interest.

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