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Research on Quality Control and Management of Construction Engineering

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Abstract: ***This article focuses on the research of construction quality control and management in building projects, and explores its key role in ensuring project quality. The article first clarifies the basic concepts and key links of quality control and management. Based on the comprehensive development project of China Communications Future Science and Technology Innovation City, it analyzes the problems faced in practical application and their causes, and puts forward optimization suggestions. Through empirical research design and data analysis, the main factors influencing engineering quality are revealed, and the actual effects of quality control measures are analyzed in combination with cases. The research results show that enhancing the construction technology level, strengthening personnel training and improving the supervision mechanism are important paths to improve the project quality. The conclusion emphasizes the significance of scientific management and strict control, and points out that in the future, attention should be paid to the application of new technologies and the improvement of systems.***

Keywords: Construction Engineering; Quality control Management; Empirical Analysis; Improvement measures.

1. INTRODUCTION

With the rapid advancement of urbanization in our country, the construction quality of building projects has increasingly become a key element in maintaining social stability. The continuous expansion of urbanization construction scale has put forward higher requirements for the safety, durability and functionality of building structures. The construction quality is directly related to the safety of people's lives and property. Once quality defects occur, such as foundation settlement or structural cracks, it may lead to major accidents like building collapse, causing incalculable casualties and property losses. High-quality construction projects are the cornerstone of the healthy development of urbanization. They support the improvement of urban infrastructure and the enhancement of the living environment, providing a reliable guarantee for sustainable economic development. Against the backdrop of increasingly fierce competition in the construction industry, strengthening construction quality control and management can not only enhance the core competitiveness of enterprises, but also promote technological innovation and the process of standardization, achieving a leap in the overall level of the industry. Through systematic quality management, such as the introduction of the ISO9001 quality management system, construction enterprises can optimize resource allocation, reduce rework and waste, and thus ensure that the final output meets national standards and user requirements while guaranteeing project progress.

In recent years, frequent quality accidents during the construction process of building projects have drawn widespread social attention. Most of these accidents are caused by unstandardized management and inadequate application of technology. Some construction enterprises lack a sound quality supervision mechanism, which leads to the inspection during the construction process being merely a formality and failing to detect potential hazards in a timely manner. The lagging update of construction technology, such as the insufficient application of new BIM technology, has affected the precision and efficiency of the process. These problems not only expose the shortcomings in personnel training, but also highlight the lack of quality control in the material procurement process. This paper first analyzes the quality management situation and quality management theory of the China Communications Future Science and Technology Innovation City Comprehensive Development Project, aiming to deeply explore the importance of construction quality control and management in building engineering, systematically analyze the current core problems, and then propose targeted improvement measures based on the empirical research of numerous projects. By integrating theoretical frameworks and practical cases, the research will provide the construction industry with operational management strategies and technical support, helping to enhance the quality level of projects and achieve sustainable development in urbanization construction.

2. BRIEF DESCRIPTION OF THE CONCEPT

Quality control and management in construction projects are the core elements to ensure the success of the project.

Quality control (QC) refers to a series of operation techniques and activities implemented during the construction process to continuously meet the established quality requirements. This process consists of three major links: pre-prevention (such as plan review and material pre-inspection), in-process monitoring (such as process inspection and on-site supervision), and post-event assessment (such as acceptance and testing). It is a key aspect of the implementation of the quality management (QM) system. Quality management is a broader concept. According to international standards such as ISO 9000, it involves establishing quality policies and objectives at the organizational level and achieving them through interconnected processes such as quality planning (QP), quality assurance (QA), quality control (QC), and quality improvement (QI). In the field of construction engineering, effective quality control is directly related to the formation of physical quality, which can ensure structural safety and functional reliability, while reducing accident risks and rework costs, and enhancing the overall reputation of the project. Systematic quality management runs through the entire project life cycle, integrating resources, coordinating processes, and clarifying rights and responsibilities. Usually, the construction project manager assumes the highest responsibility to ensure a high degree of alignment between quality goals and organizational strategies.

The efficient implementation of construction quality control cannot be achieved without precise control over key links. Material procurement, as the material basis, involves the quality source control of raw materials, components and turnover materials, etc. It is necessary to establish a strict supplier evaluation system, on-site acceptance system (including witnessed sampling and testing) and warehouse management system to prevent substandard products from entering the construction site. The selection and implementation of construction techniques and methods are equally crucial. Scientific construction organization design, advanced techniques and methods (such as the application of BIM technology and prefabricated construction), as well as operation procedures that comply with standards, are the direct guarantees for ensuring that the physical quality meets the standards. Personnel factors have a decisive impact. From the decision-making management to the front-line operators, their quality awareness, professional skills and sense of responsibility are directly related to the implementation effect. Therefore, it is necessary to implement strict qualification reviews, continuous skills training and assessment incentive systems. The ultimate goal of quality management is to ensure that the engineering entity complies with national mandatory standards, design documents, contractual agreements, and the specific requirements of the construction entity, while achieving the comprehensive optimum of progress, cost, and quality [1]. Its core principles include the full-process coverage of Total Quality Management (TQM), prevention first (emphasizing process monitoring rather than post-event remediation), scientific decision-making and fair evaluation based on data and facts, as well as a continuous improvement mechanism achieved through the quality cycle (PDCA cycle). These concepts and principles together form the solid theoretical foundation for project quality control.

3. THEORETICAL ANALYSIS

Firstly, based on the comprehensive development project of China Communications Future Science and Technology Innovation City and common quality management problems, a quality cause analysis and impact analysis were conducted to form an actual construction quality management theory, as shown in Table 1.

Table 1: Quality Issue Analysis Table

Problem category	Specific issues	Cause analysis	Influence
The control and management of construction raw materials and mechanical equipment are insufficient	*Centralized procurement leads to costs exceeding the budget*	*To avoid the shortage of raw materials affecting the construction progress, construction units often purchase a large amount of raw materials in a centralized manner*	*Waste of funds and costs exceeding the budget*
Environmental issues	*The quality of construction is affected by environmental factors*	*Managers need to consider the impact of changes in environmental factors on construction quality*	*Quality defect*
The construction quality inspection during the construction period was not up to standard	*The sampling inspection method has limitations and one-sidedness*	*Most units adopt the method of sampling inspection to test the construction quality*	*Quality risks have not been fully investigated*
Construction technology issues	*The construction methods and technical measures are not reasonably formulated*	*The design intent was not fully grasped, the design content was not reviewed, and construction was not carried out in accordance with the plan*	*The quality of the project is affected*
The management responsibilities are not clear	*The quality responsibility is not clear*	*The management personnel failed to clarify the management concept, and the quality management and power*	*It is difficult to identify the person responsible for engineering quality*

The management system is not perfect	*The management process is not clear and the responsibility allocation is not definite*	*distribution were unreasonable* *The management system design is unreasonable and the supervision mechanism is not sound*	*problems* *The difficulty of construction efficiency and quality control has increased*
Backward technical means	*Most construction sites rely on traditional quality control methods*	*Lack of advanced detection technologies and equipment*	*The construction progress and project quality have been affected*
The quality of the personnel varies greatly	*There are significant differences in the technical proficiency and quality awareness among workers*	*Some workers lack skills training and have insufficient understanding of construction norms and quality standards*	*The consistency and reliability of construction quality have been affected*
The construction of quality culture is insufficient	*The quality culture construction of construction enterprises is insufficient*	*Enterprises neglect quality education and lack systematic training plans and continuous improvement activities*	*The enterprise does not pay enough attention to and attach sufficient importance to quality internally*
Poor cost control in construction projects	*The cost control mechanism is not perfect*	*Enterprises have not fully recognized the importance of cost budgeting*	*Cost loss harms the interests of both parties*
The overall coordination and management of construction projects are relatively poor	*Managers have not recognized the importance of overall coordinated management*	*With the traditional management model, communication among departments is not smooth*	*On-site management is disorderly and responsibility allocation is not clear*
The skills of construction workers need to be improved	*Construction technicians need to understand industry professional knowledge and combine it with practical application*	*The management personnel have limited capabilities and their professional knowledge is not systematic*	*Low management effectiveness*
There are deficiencies in the quality supervision system of construction projects	*The design of the supervision system is unreasonable and the implementation links are insufficient*	*The supervision system may not have fully taken into account the complexity and diversity of construction projects when it was formulated*	*Insufficient supervision makes it difficult to detect and solve quality problems in a timely manner*
The quality of construction project management personnel within the enterprise is relatively low	*Technical requirements have been raised, and there are demands for multiple specialties*	*During the construction process of engineering projects, multiple specialties are involved. Managers need to connect the professional knowledge they have learned with actual work*	*Low professional quality has an impact on the significant improvement of the quality of engineering construction*
Quality issues in the selection and storage of construction materials	*The selection of materials should strictly refer to the standardized requirements for materials in architectural engineering design*	*Inferior or substandard construction materials can affect the construction quality of building projects*	*The construction quality has been affected*

The theoretical framework of construction quality control in building engineering is based on systems theory, cybernetics and total quality management (TQM), covering the PDCA cycle, ISO9001 standard system and process control model. The core lies in achieving systematic management of engineering quality goals through quality pre-control in the design stage, dynamic monitoring during the construction process, and closed-loop feedback in the acceptance stage. However, in practical application, there are multiple structural contradictions: the centralized procurement of materials leads to costs exceeding the budget, which is due to the excessive avoidance of supply risks by construction units; The partial exposure Statistical Quality control (SQC) method of sampling inspection has insufficient adaptability in the construction scene and fails to cover key nodes such as concealed works. The unreasonable formulation of technical measures reflects the insufficient depth of BIM technology application and the existence of a gap in the transmission of design intentions. More fundamentally, the responsibility matrix is ambiguous. For instance, the unclear definition of the quality responsibility subject leads to difficulties in traceability, which is directly related to the implementation deviation of the current GB/T50326 project management specification.

In response to the above problems, international cutting-edge research has proposed integrated solutions. The ASCE case library in the United States shows that adopting the JIT (Just-In-Time) material management model can reduce inventory costs by 23%, while introducing non-destructive testing technologies (such as infrared thermal imaging) can increase the detection rate of quality defects by 40%. In terms of optimizing the management system, the on-site management experience of Japan's "Five Constants Method" can be drawn on, and quality control nodes can be clearly defined through visual responsibility boards. Domestic empirical research shows that the quality information platform based on BIM can achieve multi-party collaboration among design, construction and supervision, and eliminate more than 30% of technical briefing errors. At the same time, the supervision mechanism needs to be restructured: The "CONQUAS" assessment system of the building and Construction Authority (BCA) of Singapore has demonstrated that incorporating performance indicators such as material durability and structural reliability into the scoring dimensions can significantly enhance the effectiveness of quality process control. These measures collectively point to the transformation of the quality control paradigm -

from the traditional experience-driven to the data-driven intelligent decision-making model.

4. EMPIRICAL RESEARCH DESIGN

To comprehensively evaluate the practical operation process and effect of construction quality control and management in building projects, this study designed a rigorous empirical scheme, focusing on the selection criteria of the research objects. The research team selected a variety of engineering projects as samples, covering types such as residential buildings, commercial complexes and public facilities, to ensure representativeness and coverage. The selection criteria are based on the differences in construction stages, including key links such as foundation construction, main structure construction and decoration finishing, to observe the dynamic changes of quality control and management at different stages. The quality control level of the project is taken as the core screening indicator and is classified into three categories: excellent, average and poor. For instance, benchmark projects that have won national quality awards are compared with cases that have quality accidents. This stratified sampling method, taking into account factors such as scale, geographical location and construction period, avoids sample bias and ensures the universality and reliability of the research results. After the initial screening, 30 representative projects were finally determined, covering the developed eastern coastal areas and the developing central and western regions, taking into account the differences in urbanization processes, providing a solid foundation for subsequent data analysis [2] As shown in Figure 1.

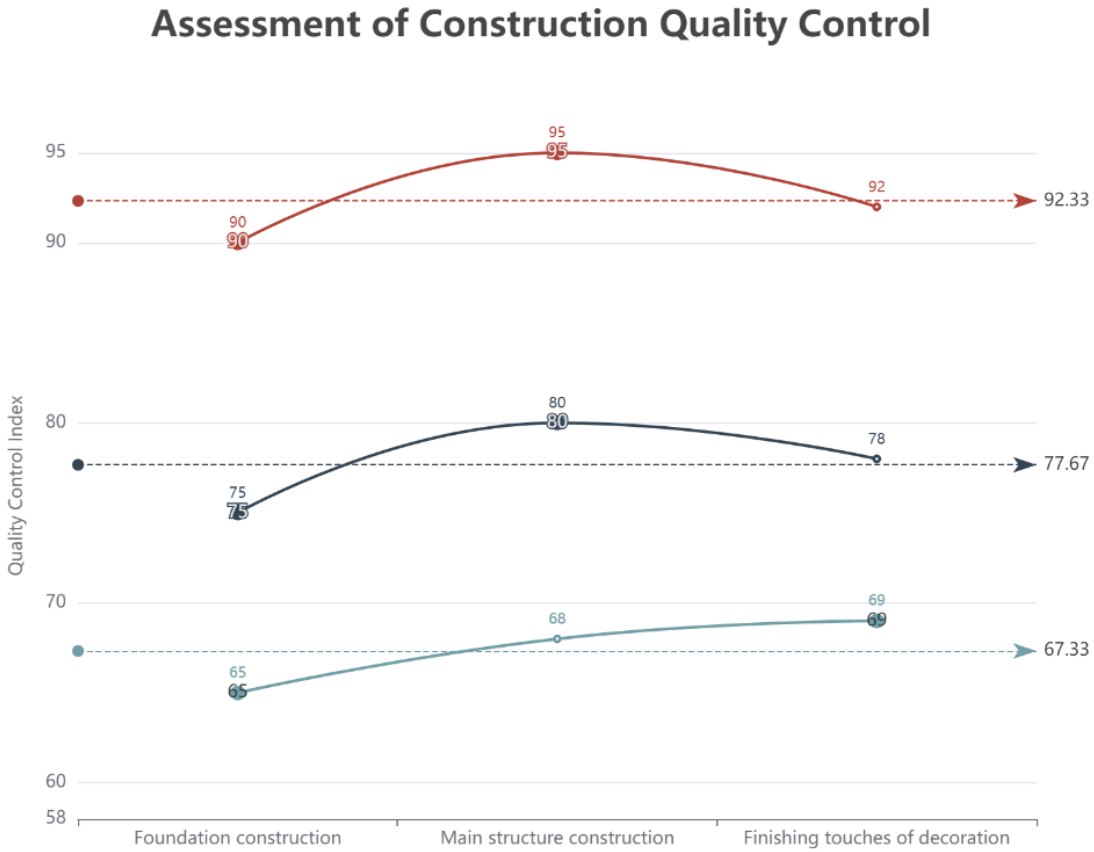

Figure 1: Assessment of Construction Quality Control

Data collection was carried out using multi-source methods, including investigation interviews, on-site inspections, document reviews and questionnaire surveys, etc. Field research involves delving into the construction site, interviewing project managers, engineers and workers, and obtaining first-hand insights into the quality control process, such as material acceptance standards and process execution details. On-site inspection ensures the real-time and accuracy of data by observing the construction process and recording the quality control measures of key nodes such as concrete pouring and steel bar binding. Document review focuses on quality plans, inspection reports and nonconformity records, and analyzes historical data to identify systemic defects. Questionnaires were widely distributed to construction workers and management to collect subjective feedback on the quality management system. Data analysis tools include checklists and verification forms for initial quality defect screening, statistical sampling methods such as random sampling to assess the qualification rate of materials,

performance reviews to compare the delay rates of different projects, and root cause analysis to trace the source of accidents. The research model incorporates the golden section concept, optimizes the resource allocation model, simulates the distribution of quality control nodes, and enhances the evaluation efficiency. Correlation analysis was conducted through SPSS software to quantify the association between management strategies and engineering quality indicators, ensuring the depth and practicality of the research.

5. EXPERIMENTAL RESULTS AND ANALYSIS

Table 2: Quality Issue Analysis Table

Case Number	Case Background	Quality issue	Influencing factors	Quality control measures	Actual effect	Improvement suggestions
Case21	The comprehensive development project of China Communications Future Science and Technology Innovation City	The anti-seepage requirements for basements are high	Construction technology level and the quality of management personnel	Prepare the project quality plan and conduct full-process control	The quality of the project is strictly controlled	Strengthen construction management and enhance the quality of personnel and construction capabilities
Case22	Equipment installation for a steel plant project of China Communications Construction Company	The raw material unloading funnel sank and the supporting crossbeam deformed	The design load value is small and the support strength is insufficient	Strengthen construction supervision to ensure reasonable design	Analyze the cause of the accident and propose improvement measures	Clarify design requirements and strengthen construction supervision
Case23	Stainless steel factory converter renovation project	The construction site is narrow and the schedule is tight	Construction site restrictions and schedule pressure	Strengthen the quality control of construction procedures	To achieve the goal of prevention first	Clarify quality control points and formulate countermeasures and measures
Case24	A certain smelting engineering construction project	Ensure the project quality	The establishment of the quality policy and objectives	Determine the quality policy and objectives, and develop new construction methods	The rate of high-quality products per unit project has reached 90%	Persist in improvement to reach the forefront of the industry
Case29	Medium and heavy plate engineering	High standards and strict requirements	Full-process control of construction quality	Prepare a quality plan to ensure the quality of the project	Received high praise from the owner	Continue to maintain high standards and strict requirements to ensure quality

Based on the data collection and analysis of the previous empirical research design, this study, through on-site investigation and quantitative statistics of multiple construction projects, reveals the key factors affecting construction quality. Data analysis was conducted using SPSS software for regression analysis and variance test. The results indicated that the construction technology level, the quality of management personnel and the supervision mechanism were the three core influencing factors，As shown in Figure 2 . Specifically, the level of construction technology directly determines the stability and durability of the engineering structure. The quality of management personnel affects the achievement of overall quality goals through decision optimization and execution efficiency. The effectiveness of the supervision mechanism is reflected in preventive control. For instance, in the case 21 of the China Communications Future Science and Technology Innovation City Comprehensive Development Project, the high anti-seepage requirements for the basement in the main electrical room project originated from the shortage of construction technology and management personnel. However, through the formulation of the project quality plan and the implementation of full-process control, the project quality was significantly improved, which confirmed the importance of strengthening construction management. The data also shows that a weak supervision mechanism can easily lead to the accumulation of defects. For instance, in the steel plant equipment installation project of Case 22, the deformation accident of the support crossbeam was caused by insufficient design load value. However, after strengthened supervision, the risk was identified in time, thus avoiding greater losses. These findings emphasize that in construction projects, technical standardization, institutionalization of personnel training and normalization of supervision are the foundations for improving quality, and the management process needs to be continuously optimized through the PDCA cycle.

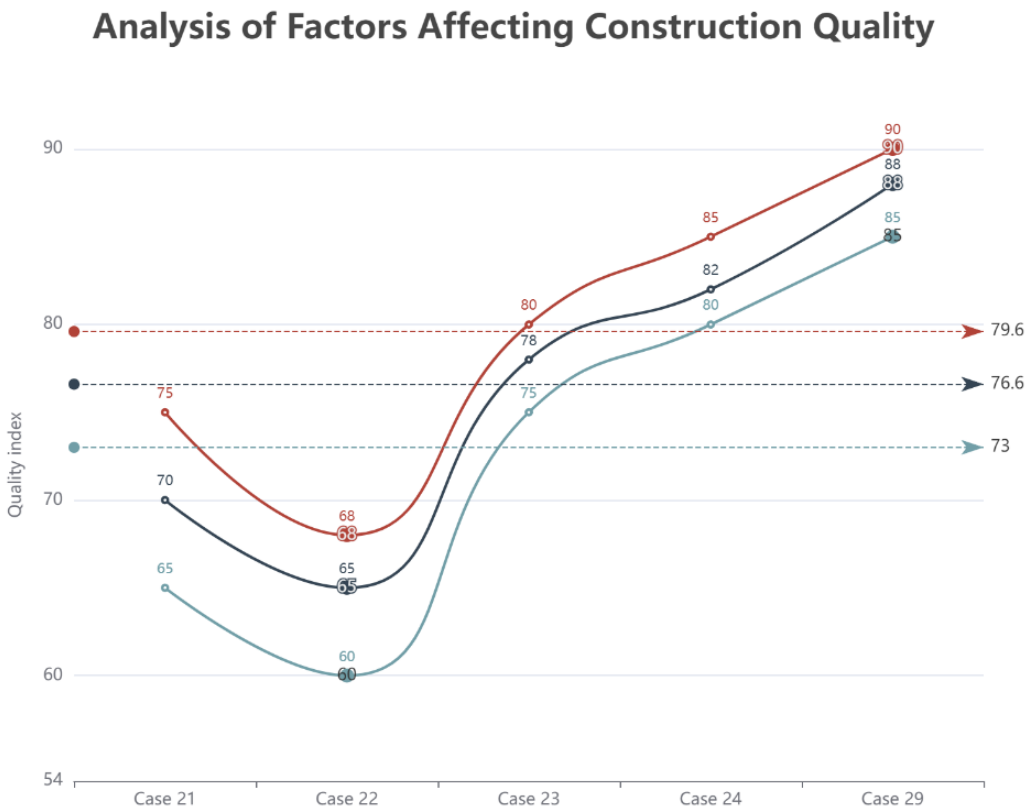

Figure 2: Analysis of Factors Affecting Construction Quality

Through in-depth analysis of typical cases, the actual effect of quality control measures has been verified. In Case 23, the converter renovation project of the stainless steel plant was confronted with a narrow construction site and tight schedule. By strengthening the quality control of the construction process, such as introducing BIM technology for process simulation, the goal of prevention first was successfully achieved, reducing the rework rate. Similarly, in Case 24, the smelting project raised the rate of high-quality products per unit project to 90% by determining the quality policy and objectives and developing new construction methods, demonstrating the efficiency of goal-oriented management. In Case 29, the medium and heavy plate project adhered to high-standard full-process control. After formulating the quality plan, it received high praise from the owner, demonstrating the significance of strict quality requirements. Based on these empirical studies, improvement suggestions include: strengthening construction technology training, such as using virtual reality simulation to enhance workers' skills; Improve the quality of management personnel and optimize their decision-making ability through regular assessment and continuing education. Improve the supervision mechanism and introduce third-party testing and intelligent monitoring systems to ensure real-time correction. These measures aim to build a closed-loop quality management system, promote the industry towards lean development, and provide an operational framework for subsequent engineering practices.

6. CONCLUSIONS AND PROSPECTS

This research systematically reviews and analyzes the theories and practices of quality control and management in construction projects, revealing several key issues currently faced by the industry in the process of quality management. Research shows that the uneven professional capabilities of construction workers and their weak quality awareness are among the main reasons for the inadequate implementation of construction techniques. Typical problems such as insufficient compaction of concrete and non-standard lap joints of waterproof layers occur frequently, affecting the quality and safety of the project. In terms of material management, some projects have problems with lax supply chain control. The qualification review of suppliers is merely a formality, and the re-inspection system for materials upon entry is not effectively implemented. As a result, substandard key building materials such as steel bars and cement flow into the construction site, posing safety hazards.

In terms of construction process control, traditional management methods have obvious shortcomings, especially in concealed works and key procedures, where there is a lack of effective supervision. Quality inspections mostly

rely on subjective experience and judgment, and there is a lack of digital and standardized real-time monitoring means, making it difficult to achieve full-process quality tracking. At the management system level, some enterprises have not yet established a complete responsibility implementation mechanism. There is a disconnection between quality planning and on-site execution, and the PDCA cycle has not formed an effective closed loop, resulting in the recurrence of common quality problems that are difficult to cure.

In response to the above problems, the research has proposed a series of multi-level improvement paths. Firstly, a quality culture system involving all staff should be established. This can be achieved by setting up a standardized operation video library, introducing a VR quality training platform, and conducting accident case warning education to comprehensively enhance the operational standardization and risk prevention awareness of construction teams. In terms of material management, it is suggested to strengthen the supplier flight inspection system, implement material traceability coding management, conduct third-party blind sample spot checks on bulk building materials, and combine Internet of Things technology to achieve real-time upload and cloud comparison of on-site acceptance data, thereby enhancing the controllability of material quality.

In terms of construction process control, it is urgently necessary to promote BIM-based digital twin technology, especially at key construction nodes such as deep foundation pit support and large-volume concrete pouring. Sensor networks should be deployed to achieve intelligent monitoring and early warning of key parameters such as temperature control and settlement, thereby enhancing the controllability and transparency of the construction process. In terms of optimizing the management system, the quality responsibility matrix should be restructured. Key links such as design handover, process handover, and concealed acceptance should be incorporated into the blockchain evidence storage system to ensure the completeness and traceability of the quality traceability chain. Moreover, the process should be optimized through the lean construction concept to reduce ineffective links and enhance management efficiency.

Looking to the future, research on quality management in construction projects should focus on two dimensions: technological integration and innovation in management mechanisms. In terms of technological application, it is necessary to deeply explore intelligent detection technologies such as machine vision recognition of wall flatness deviation, unmanned aerial vehicle (UAV) aerial surveying of earthwork volume, and AI algorithm prediction of early strength of concrete, and promote the research and development of self-sensing and self-regulating intelligent building material systems. At the management level, a quality big data platform covering the entire life cycle of the project should be constructed, integrating design parameters, construction logs, monitoring data and operation and maintenance feedback information. By leveraging machine learning methods, a quality risk prediction model should be established to achieve the forward movement and precise control of quality management.

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