Journal of World Architecture, 2025, Volume 9, Issue 6
https://ojs.bbwpublisher.com/index.php/JWA
Online ISSN: 2208-3499
Print ISSN: 2208-3480

Research on Key Issues and Solutions in Construction Engineering Quality Control

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Abstract: The quality of construction engineering is not only related to the service function and service life of the project, but also directly affects the safety of people's lives and property. At present, although China's construction industry is gradually moving towards standardization, there are still some problems in the quality control link. It is necessary to formulate systematic solutions based on the root causes of the problems. Starting from four key dimensions: construction materials, construction personnel, construction technology and construction management, this paper elaborates on the prominent problems in construction engineering quality control and puts forward targeted solutions, so as to provide reference for improving the overall performance of the project and optimizing the construction quality management.
Keywords: Construction engineering; Quality control; Key issues; Solutions

Online publication: December 31, 2025

1. Introduction

In the whole process of construction engineering, quality control is the core link to ensure the safe, economical and efficient completion of the project. It runs through the entire life cycle of the project and directly affects the service life, service function and safety of the building. The improvement of construction engineering quality problems benefits from engineering management, in which construction engineering quality control plays an important role. Therefore, it is of great significance to strengthen the analysis of key issues in construction engineering quality control, promote the standardized and refined development of the construction engineering quality and safety management system, and improve the overall quality of construction engineering.

2. Analysis of key issues in construction engineering quality control

2.1. Human factors: Insufficient quality awareness and professional capabilities

Personnel are the core implementers of quality control, and their deficiencies in awareness and capabilities directly lead to ineffective management and control. For instance:

(1) Short-sighted operations of managers: Affected by the assessment orientation of "progress first and cost supremacy", some project managers ignore quality standards [1]. For example, to deliver residential projects 30 days in advance, the compaction degree detection process of foundation backfill soil was arbitrarily simplified. Instead of detecting 1 point per 100 m^2 in accordance with specifications, the compaction effect was only judged by the naked eye. This led to uneven settlement of the building and through cracks on the walls in the later stage, laying potential safety hazards;

(2) Non-standard operations of construction workers: Migrant workers account for a high proportion of front-line construction personnel, most of whom have not received systematic training and rely on experience for construction [2]. During concrete pouring, some workers expanded the vibration spacing to 80 cm and shortened the vibration time to 10 seconds, resulting in honeycombing and holes inside the concrete. During wall masonry, the thickness deviation of mortar joints reached 5–20 mm, the verticality exceeded the standard, and the surrounding areas of door and window openings were prone to cracking due to uneven stress;

(3) Lack of sense of responsibility among inspectors: There are problems of "loose data control" and "simplified processes" in the quality inspection link. During steel bar inspection, some personnel reduced the number of samples or failed to carefully verify the tensile strength data, allowing unqualified steel bars to enter the construction site. Concrete test blocks were not cured according to standards and only placed in a normal temperature environment, resulting in falsely high detected strength that cannot reflect the actual quality of the structure.

2.2. Material factors: Some loopholes in the whole-chain management and control

Materials are the material basis of project quality, and there are risks in the whole process from procurement to storage. The loopholes are as follows:

(1) Ignoring quality standards in the procurement link: To reduce costs, some enterprises choose "low-price bidding" in material procurement and ignore quality standards [3]. For example, the purchased HRB400E steel bars have a yield strength of only 350MPa (specification ≥ 400MPa) and a tensile strength of 480MPa (specification ≥ 540MPa). The 1.5mm thick SBS waterproof coiled material (specification requirement ≥ 3 mm) cracks and leaks after 1–2 years of use. The thermal conductivity of thermal insulation materials is 0.045W/(m·K) (specification ≤ 0.030W/(m·K)), resulting in substandard building energy-saving effects;

(2) Failure to implement the acceptance link effectively: The "sampling inspection" system was not strictly implemented for incoming materials, and quality was only judged by appearance inspection. The strength of wall blocks was not tested, leading to hollowing in the later stage. The insulation performance of wires and cables was not tested, and some products had insufficient insulation layer thickness, posing a risk of electric leakage during use. The chloride ion content of concrete admixtures was not tested, which accelerated steel bar corrosion and shortened thestructural life.

(3) Improper storage in the storage link: The storage conditions at the construction site are simple and crude. Cement is stacked outdoors and gets damp and agglomerated, leading to reduced strength. Steel materials are not rust-proof treated, and surface rust reduces the bonding force with concrete. Wood is not anti-corrosive and insect-proof, making it prone to decay and insect infestation. Moreover, materials

are stacked mixed (such as cement and lime), increasing the probability of misuse by workers [4].

2.3. Technical factors: Unreasonable schemes and lagging application of new technologies

Technical schemes are the core support for quality control, and defects at the technical level directly lead to quality problems. For example:

(1) Lack of pertinence in technical schemes: General templates are copied without combining with the actual situation of the project. For soft soil foundation treatment, only the replacement method is adopted without considering the distribution thickness of soft soil, resulting in the foundation bearing capacity failing to meet the design requirements and excessive building settlement. Concrete column pouring of high-rise buildings is not carried out in layers, causing concrete segregation and uneven strength distribution. No special scheme is formulated for construction in northern winter, and the concrete strength is unqualified after freezing, requiring chiseling and re-pouring;

(2) The application of new technologies fails to achieve the expected results: The grouting of prefabricated building joints is not full, some sleeves have gaps, and the bearing capacity is insufficient. BIM technology is only used for 3D modeling without collision inspection, and pipeline conflicts are found during construction, requiring temporary changes. Intelligent monitoring equipment only records data without establishing an early warning mechanism. The mass concrete is not cooled in time when overheated, resulting in temperature cracks [5];

(3) Incomplete technical disclosure: The disclosure of steel bar binding does not clarify the anchorage length and lap length. The waterproof construction does not mention the base treatment standard, leading to blistering and falling off of coiled materials. There is no follow-up after disclosure, and workers still use manual vibration instead of machinery, resulting in poor concrete compactness.

2.4. Management factors: Imperfect mechanisms and inadequate implementation of responsibilities

A sound management mechanism is the key to quality assurance, and system defects lead to ineffective management and control. To give examples:

(1) Imperfect quality management system: The ISO9001 system does not refine the implementation process, and quality inspections have no clear frequency (daily once a day, weekly once a week), content and rectification requirements. There is a lack of a traceability chain of “materials–processes–personnel”, making it impossible to determine the cause of wall cracks. Regular quality training is not carried out, and the personnel’s capabilities cannot be improved [6];

(2) Insufficient coordination among participating parties: The design unit fails to timely respond to technical questions, and the construction unit makes arbitrary changes. The supervisor does not station at the concealed works, and the construction unit mixes construction waste and uses fewer steel bars. The construction unit shortens the construction period and frequently changes the design, resulting in chaotic processes. There is no unified communication platform, leading to delayed information transmission [7];

(3) Lack of risk and emergency mechanisms: No rainproof cloth (more than 500 m^2 required) or water pumps (lift $\geq$ 10m required) are prepared in the rainy season, resulting in foundation pit water accumulation and collapse. There are no cooling measures in high temperatures, leading to concrete

cracking. There are no alternative suppliers, and inferior materials are used when materials are out of stock. Quality problems are only superficially repaired, and wall cracks occur repeatedly.

3. Solutions to key issues in construction engineering quality control

3.1. Personnel dimension: Strengthen awareness and improve professional capabilities

To address the problems caused by human factors, a threefold mechanism of "training + assessment + restraint" is needed to comprehensively improve personnel quality.

3.1.1. Conduct hierarchical and classified training

For managers, they should organize monthly quality-themed courses to learn industry standards and specifications, analyze accident cases such as foundation settlement and floor deformation, carry out simulation drills for progress-quality conflicts, and strengthen the awareness of "lifetime quality responsibility system". For construction workers, pre-job training shall be no less than 20 class hours, covering process specifications such as concrete vibration and steel bar binding, supplemented by graphic manuals and operation videos; on-the-job rotation training shall be conducted quarterly, with on-site teaching targeting problems such as mortar joint deviation and irregular vibration, and only those who pass the assessment can take up the job [8]. For inspectors, they should participate in industry skill training every six months to learn standard processes such as steel bar sample extraction and concrete test block curing; conduct "blind sample testing" assessments, sign the "Integrity Commitment for Testing", establish credit files, and violators shall be included in the industry blacklist.

3.1.2. Improve assessment incentives and constraints

Quantify assessment indicators should be based on the assessment of managers on "qualified rate of quality acceptance" and "closed-loop rate of rectification"; assess construction teams on "one-time qualification rate of processes" and "rework rate", accounting for 60% of performance. Those who fail to meet the standards will have their performance deducted or be transferred.

Positive incentives are as follows:

(1) Select "Quality Star" and "High-Quality Team" monthly;

(2) Give priority to promotion for annual outstanding individuals;

(3) Issue bonuses by selecting excellent individuals and teams to further improve the qualified rate of concrete pouring.

Responsibility constraints: All positions shall sign quality responsibility commitments to clarify the whole-process responsibilities from material acceptance and process construction to testing In case of quality accidents, trace the responsible persons through the commitments and pursue legal liability. For example, personnel involved in steel bar testing fraud shall have their qualifications revoked.

3.2. Material dimension: Full-chain control to eliminate problematic materials

Build an integrated management and control system of "procurement–acceptance–storage" to ensure material quality from the source:

3.2.1. Optimize procurement management and carefully select suppliers

A supplier access system should be established to score suppliers from four dimensions: qualifications (business license and production license), production capacity (supply volume in the past three years), quality (qualified rate of test reports), and service (timeliness of delivery).

Suppliers with a score of 80 or above are included in the list, which is updated quarterly, while suppliers with quality problems are eliminated. “Sunshine procurement” should be implemented, with bulk materials such as steel bars and cement centrally purchased by enterprise headquarters through open bidding on public resource platforms. The comprehensive scoring method is adopted for bid evaluation, with weights of 40% for quality, 30% for price, and 30% for service, to avoid low-price bidding. Detailed contracts are signed to clarify quality standards, testing requirements, and liability for breach of contract; for important materials, a quality deposit of 5–10% is reserved and paid only if no problems occur one year after completion acceptance.

3.2.2. Standardize acceptance testing and strictly control the entry of materials

The “double-person acceptance + sampling inspection” mechanism should be implemented. When materials enter the site, construction personnel and quality inspectors jointly verify the certificate of conformity. After passing appearance inspection, samples are taken according to specifications, such as one batch of steel bars per 60 t, and sent to a CMA-qualified institution for testing. Materials shall not be used before the test report is issued, and unqualified materials shall be returned immediately. A testing information platform should be established to upload test reports for inquiry by the construction, construction management, and supervision units, with an early warning function to automatically prompt unqualified materials. In addition, equipment calibration records of testing institutions should be regularly checked to eliminate false reports [9].

3.2.3. Improve storage conditions and reduce losses

Special warehouses should be built according to material characteristics. Cement warehouses are raised by 30 cm to prevent moisture and ensure ventilation; steel warehouses are equipped with rain shelters, stacked by category, and coated with anti-rust paint; wood warehouses are kept well-ventilated and dry and treated with anti-corrosion agents. The management of receiving and issuing materials should be standardized, with construction teams filling in receiving orders that are jointly verified by the team leader and warehouse manager. Accounts are updated after receipt, and weekly inventory checks are conducted to improve material utilization efficiency.

3.3. Technical dimension: Optimize schemes and promote technological innovation

Focusing on “scientific schemes + technological implementation”, the level of technical management and control should be improved by strengthening systematic planning, optimizing technical solutions, and promoting the application of information technologies to enhance precision, efficiency, and overall management effectiveness.

3.3.1. Refine scheme formulation and demonstration

Schemes should be formulated in combination with project reality. For soft soil foundation projects, detailed exploration of soil distribution and water content should be carried out, and appropriate methods such as replacement or high-pressure jet grouting piles should be selected. For winter construction, five-year meteorological data should be collected to formulate special schemes including hot water mixing, antifreeze admixtures, and thermal covering measures. Scheme review should be strengthened for major and dangerous projects, such as steel structures with spans of 36 m or more and foundation pits with depths of 5 m or more, by inviting more than five experts to conduct reviews and issue written opinions, and any scheme changes should be re-demonstrated. For example, super high-rise projects can optimize concrete pouring schemes through expert review to avoid temperature cracks.

3.3.2. Promote the standardized application of new technologies

At present, mature information technology and advanced digital technology have been widely applied in construction engineering, providing favorable conditions for quality management and control. In prefabricated buildings, sleeve deviation is checked to be no more than 2 mm when components enter the site, laser calibration is used during installation, grouting pressure is controlled at 0.2–0.4 MPa, and grouting fullness is inspected with an endoscope, with immediate re-grouting required if unqualified. BIM technology is used to conduct collision inspections at the design stage to reduce construction changes, simulate construction progress and mark quality control points during the construction stage, and compare the model with the physical structure at the acceptance stage to improve acceptance efficiency. Intelligent monitoring systems are applied by installing temperature sensors for mass concrete to automatically alarm in cases of overheating and enable timely installation of cooling water pipes, as well as displacement sensors for deep foundation pits to activate emergency measures when settlement exceeds 5 cm.

3.3.3. Strengthen technical disclosure and tracking

Hierarchical disclosure should be implemented, with the technical director explaining key difficulties of the scheme to team leaders, who then convey detailed operational requirements to workers, supported by node diagrams and instructional videos, and a "question box" established to provide 24-hour responses and ensure full understanding. On-site tracking should be strengthened, with technicians conducting inspections every two hours, using steel bar position detectors and concrete rebound testers to verify quality, correcting irregular operations such as manual vibration, and ensuring effective implementation of the scheme.

3.4. Management dimension: Improve mechanisms and strengthen coordination and risk response

A management system integrating "system + coordination + risk" should be established to ensure comprehensive quality management and control without loopholes.

3.4.1. Improve the quality management system

The ISO9001 process should be refined by clearly defining the frequency of quality inspections, including daily inspections, weekly inspections, and monthly inspections, the inspection content, such as daily checks of process specifications, weekly inspections of concealed works, and monthly inspections of material quality, as well as rectification requirements, with 24 hours for general issues and 48 hours for major issues. System implementation should be strengthened by establishing a headquarters quality supervision team to conduct monthly inspections of project records, circulating criticisms for failure to implement the system, and linking implementation performance with evaluations to prevent "empty system operation."

3.4.2. Establish a traceability system

Coded management of materials, processes, and personnel should be implemented to enable full-process traceability and quickly identify causes when problems occur. Coordination among participating parties should be strengthened through regular coordination meetings, including weekly quality coordination meetings in which the construction unit reports problems, the design unit responds to inquiries, the supervision unit reports inspection results, and the construction unit proposes requirements, with meeting minutes formed to clarify rectification responsibilities [10]. Coordination agreements should be signed to define the responsibilities of all parties, including prohibiting arbitrary shortening of construction periods by the construction unit, requiring the design unit to respond within 24 hours, ensuring construction in accordance with specifications, and mandating on-site supervision, while agreeing on joint and several liabilities with proportional responsibility for quality issues. An information platform should be established to enable real-time sharing of construction progress, quality inspections, and test data, reducing the time required to resolve design issues from 48 hours to 24 hours.

3.4.3. Strengthen risk and emergency management and control

Risk identification and response should involve all personnel, who identify potential natural, material, and technical risks before construction begins, classify them according to “possibility + impact,” and develop measures for high-risk items, such as preparing 1.2 times the required rainproof cloth in the rainy season and establishing 2–3 alternative suppliers. Emergency plans should be improved by clarifying the process of “reporting–disposal–rectification–acceptance” for quality incidents. When problems occur, losses are first stopped, causes are jointly analyzed with all participating parties (e.g., checking materials, construction, and design for wall cracks), and construction is resumed only after rectification and acceptance are completed to reduce potential losses.

4. Conclusion

In summary, with the acceleration of urbanization and the continuous improvement of people’s material living standards, the demand for construction engineering has become increasingly diversified. Construction engineering is in urgent need of developing in the direction of large scale, high level and diversification to meet the social demand for engineering projects such as highway and bridge construction, large public facilities, prefabricated buildings and green buildings. Therefore, in construction engineering projects, whether it is design, construction or management-related units, they should attach sufficient importance to the key issues affecting project quality, adhere to the principles of adapting to local conditions and seeking truth from facts, prevent common quality problems that may occur during construction in advance, and formulate preventive measures in advance. By improving personnel’s quality awareness and professional capabilities, strictly controlling material quality, realizing refined management of construction technology, improving the management system, and ensuring timely follow-up of later maintenance, the goal of high-quality development of construction engineering can be achieved.

Disclosure statement

The authors declare no conflict of interest.

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