Quality Control Measures for Building Structure Engineering Strengthening Techniques

Fuhu Liao

Zhongdao Construction Technology Co., Ltd., Hefei, Anhui, 230000, China

Keywords: Building Structure Engineering; Strengthening Techniques; Quality Control; Construction Technology; Acceptance Inspection and Monitoring

Abstract: This paper focuses on the quality control of building structure strengthening techniques, discussing it from five aspects: technical management, materials, construction technology of strengthening layers, acceptance inspection and monitoring, and the quality assurance system. Technical management emphasizes detailed design of construction drawings, technical disclosure, and dynamic adjustment. Material control covers incoming inspection, storage, and compatibility verification. Construction technology control involves bonding and anchoring processes. Acceptance inspection and monitoring include criteria for process and final acceptance, as well as long-term monitoring mechanisms. The construction of the quality assurance system encompasses standardized operating procedures, personnel qualification management, and quality responsibility tracing, aiming to comprehensively improve the quality of strengthening projects.

1 Introduction

Building structure engineering strengthening refers to technical measures taken to address issues such as insufficient load-bearing capacity and reduced durability in existing buildings caused by design flaws, construction problems, changes in use function, or environmental erosion. Its core objective is to restore or enhance structural performance through scientific and rational strengthening methods, ensuring building safety and functionality. Quality control, as a critical link in strengthening projects, runs through the entire process of design, materials, construction, and acceptance, directly determining the strengthening effect and project lifespan. This paper systematically elaborates on the quality control measures for building structure strengthening techniques from four dimensions: technical management, material control, construction technology, and acceptance monitoring.

2 Quality Control in Technical Management

2.1 Detailed Design of Construction Drawings

Construction drawings are the key carrier for transforming technical requirements into physical entities, and their level of detail directly affects construction quality. Drawing design must break through traditional annotation modes and establish a tripartite annotation system of "macro-layout – micro-construction – material parameters": at the macro level, clarify the spatial positioning of strengthening areas and their connection relationships with surrounding components; at the micro level, detail key joint drawings, such as requiring annotations for substrate removal depth, roughness control standards, and cleanliness requirements for interface treatment, and specifying anchor material, specifications, layout spacing, and embedment depth for anchoring systems, and stipulating the bonding method with the original structure and cooperative working measures for strengthening layers; at the material parameter level, list in detail the performance indicators, brand ranges, and inspection requirements for strengthening materials such as structural adhesives, fiber composites, and steel, providing quantifiable technical basis for construction [1].

2.2 Technical Disclosure and Dynamic Adjustment

  DOI: 10.25236/icacel.2025.020

Technical disclosure requires establishing a three-level disclosure mechanism of "general contractor – subcontractor – work team". Through drawing reviews, on-site demonstrations, video presentations, etc., systematically explain the operation process of strengthening techniques, key points of quality control, and safety protection measures, strengthening the quality awareness and operational skills of workers. Furthermore, a dynamic adjustment mechanism must be built. During construction, relying on equipment such as strain monitoring systems and crack observation instruments, collect structural response data in real-time. Combining construction progress and environmental changes, dynamically evaluate the strengthening effect and scheme deviations. When monitoring data exceeds warning values or significant changes occur in site conditions, promptly organize the design, construction, and supervision units for scheme optimization. By adjusting strengthening parameters, adding temporary supports, and other measures, ensure the technical scheme always remains highly adaptable to actual conditions, achieving quality control and safety assurance for the strengthening project.

3 Quality Control of Materials

3.1 Incoming Material Inspection and Storage

Incoming material inspection is the first line of defense for quality control and must strictly follow specification requirements for sampling and re-inspection. Focus on testing the direct tension bond strength between bonding materials and the substrate, as this indicator directly affects the cooperative working performance of the strengthening layer and the original structure; for structural adhesives, also inspect process parameters such as pot life and curing time to ensure constructability. Fiber materials require sampling inspection of indicators like mass per unit area and fiber diameter, while steel must be verified for mechanical properties and chemical composition. The storage stage requires targeted measures based on material characteristics: structural adhesives should be stored in dry, cool warehouses, avoiding direct sunlight which can cause performance degradation; fiber materials should be stored flat or rolled to prevent creasing affecting mechanical performance; steel should be stacked on supports and kept ventilated to prevent rust. Establish a comprehensive material ledger management system, detailing the production batch number, specifications, test report number, and specific usage location for each batch of materials, achieving full life-cycle traceability and providing basis for quality responsibility determination [2].

3.2 Material Compatibility Verification

The compatibility between strengthening materials and original structural materials is key to ensuring the long-term effectiveness of the strengthening system and must be verified through systematic tests for their compatibility: For concrete substrates, test the influence of its pH value on the curing reaction of the structural adhesive to avoid alkaline environments causing adhesive softening; for steel surfaces, study the influence of different treatment processes (e.g., sandblasting, pickling) on bond strength to optimize surface roughness parameters; when using material combinations with different coefficients of thermal expansion, assess their cooperative working ability through deformation coordination tests to prevent interface debonding due to temperature changes or load effects. Additionally, consider the electrochemical compatibility between materials to avoid accelerated corrosion caused by potential differences. Verification tests should simulate actual working conditions, using the same material batches and construction processes as the project, ensuring the representativeness of the test results. Through compatibility verification, potential risks can be identified early, material selection and structural design optimized, providing dual guarantees for the durability of the strengthening project [3].

4 Quality Control of Strengthening Layer Construction Technology

4.1 Bonding Process

The preparation and application of structural adhesive are the core of the bonding process. Use a low-speed mixer for mechanical mixing according to the ratio specified in the product manual, with mixing time controlled between 3-5 minutes, ensuring the adhesive is uniform and free of color differences. During application, use a special roller or scraper to apply the adhesive layer evenly on the substrate surface, with thickness controlled within the range of 1.5–3.0 mm; too thick prone to sagging, too thin affects bond strength. When pasting fiber materials, proceed gradually from one end to the other, using a special roller to repeatedly roll to remove air bubbles and allow the adhesive to fully impregnate the fiber bundles. The rolling pressure needs to reach 0.1–0.2 MPa. For carbon fiber fabric, adopt a "three-coat application process" , namely applying a primer coat, laying the carbon fiber fabric, and then applying a top coat, ensuring the penetration depth of the adhesive layer is not less than 80% of the fabric thickness. The curing stage requires strict control of ambient temperature and humidity; when the temperature is below 5°C, heating measures are needed; when humidity is greater than 85%, ventilation must be enhanced [4].

4.2 Anchoring Process

Anchoring construction requires precise drilling as the foundation. Use diamond drill bits for mechanical drilling, with deviations in hole diameter, depth, and verticality controlled within ±1 mm, ±5 mm, and 1.5% respectively, ensuring effective embedding of the anchor in the substrate. After drilling, use high-pressure air to blow out dust from the hole, with blowing pressure not less than 0.6 MPa and repeated not less than 3 times. Use an endoscope or hole illumination equipment to check cleanliness. Anchor agent injection requires a special injection gun, filling slowly from the bottom to the top of the hole to ensure no air bubbles remain. For prestressed anchors, dual-control indicator management must be adopted: real-time monitoring of the tensioning force value through pressure sensors, while simultaneously measuring elongation using displacement gauges. The deviation between the two must not exceed ±5% of the design value, preventing structural damage caused by over-tensioning [5].

5 Quality Control in Acceptance and Monitoring

5.1 Process Acceptance Control

Process acceptance is a key line of defense for ensuring strengthening quality, requiring the establishment of a "full-process coverage, multi-level control" acceptance system. For concealed works such as anchor installation and interface treatment, 100% physical inspection must be implemented, and high-definition video equipment should be used to retain full-process image data for traceability. During acceptance, focus on checking whether the hole diameter, depth, and verticality for anchors meet design deviation requirements, and whether hole cleanliness meets standards; parameters such as substrate roughness and moisture content after interface treatment need quantified detection using specialized instruments and compared with specification values. During the strengthening layer construction stage, phased load testing must be conducted. By simulating load effects under actual working conditions, verify the cooperative deformation ability of the strengthening layer and the original structure. Test data must be recorded in real-time and jointly confirmed by the design and supervision units. Furthermore, for geometric parameters such as strengthening layer thickness and flatness, non-contact equipment like ultrasonic thickness gauges and laser scanners should be used for non-destructive testing. Thickness deviation should be controlled within ±5%, flatness error should not exceed 2 mm/m, ensuring construction accuracy of the strengthening layer [6].

5.2 Final Acceptance Standards

Final acceptance requires comprehensive judgment from three aspects: material performance, structural bearing capacity, and appearance quality. Regarding material performance, secondary sampling inspection of specimens placed on site is required, focusing on key indicators such as the tensile shear strength of the structural adhesive and the tensile strength retention rate of the carbon fiber fabric. Test results must not be lower than 95% of the design value. Structural bearing capacity assessment needs to be completed through static or dynamic load tests. The test load should cover 1.2 times the design load, with a sustained loading time of not less than 2 hours. During this period, structural deformation, crack development, and strain response are monitored. Only when the displacement increment is less than 0.05 mm/h and the residual deformation rate is below 20% can the bearing capacity be deemed satisfactory. Appearance quality acceptance must meet the "defect-free, zero-drumming" standard. Use the percussion method combined with infrared thermography to detect drumming in the strengthening layer; the drumming area must not exceed 1% of the total area; through visual inspection and crack width gauge measurement, ensure the strengthening layer is crack-free or crack width is less than 0.05 mm; surface flatness is checked with a 2m straightedge, with deviation ≤ 3mm, and no significant color difference or peeling.

6 Construction of the Quality Assurance System

6.1 Standardized Operating Procedures

Standardized operating procedures are the cornerstone of quality assurance, requiring the construction of an operational standard system covering the entire life cycle of the strengthening project. First, compile the "Standardized Operation Manual for Structural Strengthening Engineering" based on national standards and industry experience. The manual content covers 12 major processes including material acceptance, interface treatment, strengthening layer construction, and quality testing. Each process clearly defines operating steps, technical parameters, and acceptance criteria. For example, in the interface treatment stage, the manual specifies quantitative indicators such as concrete substrate removal depth ≥ 10mm, roughness Ra value controlled within 30–50 μm, moisture content ≤ 4%, accompanied by graphic descriptions and error case comparisons. Secondly, introduce information management tools, realize electronic process inspection reporting through mobile APPs. After completing each process, construction personnel need to upload operation photos, test data, and self-inspection records. Supervisors review in real-time and sign electronic opinions, ensuring closed-loop process management. Furthermore, establish a standardized operation video library, producing 3D animation demonstrations and on-site practical operation videos for key processes (e.g., carbon fiber fabric pasting, anchor installation) for construction personnel to access and learn at any time, reducing human operational deviations [7].

6.2 Personnel Qualification Management

Personnel qualification management is a core element of quality assurance, requiring the construction of a full-chain management system of "qualification review – skills training – assessment certification". Regarding construction team selection, strictly review the enterprise's special engineering professional contracting qualifications, focusing on checking its performance in similar projects in the past three years, technical equipment level, and quality management system certification, ensuring the team has professional construction capabilities. For operator management, implement a "certification required for posting + dynamic assessment" system. All personnel engaged in strengthening construction (e.g., structural adhesive preparers, carbon fiber fabric installers, anchor installers) must pass specialized skills training organized by provincial construction authorities and obtain the "Building Structure Strengthening Operation Qualification Certificate" before starting work. Establish an annual retraining mechanism, providing continuing education on new materials, new processes, and quality common issue prevention, with training hours not less than 32 hours/year. Additionally, promote a "mentorship" model for knowledge transfer, where experienced technicians provide 6 months of on-site guidance to new hires, ensuring they master operational essentials. Through strict control of personnel qualifications, eliminate unlicensed operations and violation of rules, improving construction quality from the source [8].

6.3 Quality Responsibility Tracing

Quality responsibility tracing is an effective means to strengthen quality control, requiring the construction of a complete closed loop of "clarifying responsibility – fulfilling responsibility –

accountability". First, sign the "Quality Responsibility Letter" at the project initiation stage, clarifying the quality responsibility boundaries of all parties involved (client, design, construction, supervision), and assigning responsibilities to specific positions and individuals. During construction, implement a "quality responsibility labeling" system. After completing each process, operators paste QR code labels on the physical part. Scanning the code reveals information such as construction time, operator, test data, and acceptance records, achieving traceability of quality behavior. For quality issues that arise, immediately initiate a responsibility investigation mechanism. By reviewing construction records, surveillance videos, test reports, and other materials, accurately identify the responsible entity. Based on the severity of the problem, adopt graduated accountability measures such as economic penalties, suspension for training, and industry bans. For those causing major quality accidents, pursue criminal responsibility according to the law.

7 Conclusion

Quality control of building structure engineering strengthening needs to be based on technical feasibility, guaranteed by material reliability, centered on construction precision, and closed-loop by monitoring and verification. By constructing a full-chain quality control system of "design – materials – construction – acceptance", the safety and durability of strengthening projects can be effectively enhanced, providing technical support for the renovation and functional upgrade of existing buildings. In the future, with the development and application of new materials and new processes, quality control for strengthening must continuously optimize standard systems and promote technological progress in the industry.

References

[1] Wu Jiding. Construction Key Points and Quality Standardization Control of Planting Bar Technology in Building Structure Strengthening Engineering [J]. Popular Standardization, 2025(14): 73-74, 77.

[2] Liu Peihuan. Quality Control Measures for Building Structure Strengthening Techniques – Taking a Renovation Project in Shanghai as an Example [J]. Construction Science and Technology, 2025(11): 78-80.

[3] Sui Minghao. Research and Application of Suitable Structural Strengthening and Repair Techniques for a Historical Style Building [J]. Engineering Quality, 2024, 42(10): 66-71.

[4] Wang Jia, Yang Hui. Analysis of Construction Technology and Quality Control for Secondary Structures in Construction Engineering [J]. Engineering Technology Research, 2023, 8(13): 156-158.

[5] Ren Jiaming. Analysis of Construction Quality and Safety Management in Building Structure Strengthening Engineering [C] // Committee of Intelligent Learning and Innovation Research, China Intelligent Engineering Society. Proceedings of the 2022 Academic Forum on "Smart Planning and Management". Shandong Shengrong Construction Group Co., Ltd., 2022: 209-213.

[6] Zhang Chunye, Shen Guanglong, Sun Xiqiang. Exploration of Construction Quality and Safety Management in Building Structure Strengthening Engineering [J]. Sichuan Cement, 2021(10): 160-161.

[7] Wang Xinghong. Technical Process and Quality Analysis of Structural Strengthening Treatment for Housing Buildings [J]. Sichuan Cement, 2019(11): 148.

[8] Cao Zixu. Application Analysis of Structural Strengthening Technology in Building Construction [J]. Theoretical Research in Urban Construction (Electronic Edition), 2019(13): 130.