Key Control Factors and Countermeasures in Quality Management of Municipal Road and Bridge Construction

Guiqin Li

Huainan Municipal Gardens and Landscaping Construction Department, Huainan, Anhui, 232000, China

Keywords: Municipality; Quality management; Control factors

Abstract: Urban roads and bridges shoulder the dual missions of traffic operation and urban renewal. Their construction quality directly relates to structural durability, safe passage, and life-cycle costs. Currently, against the backdrop of rapid construction and complex environments, issues such as deviations in the implementation of design outcomes, imbalanced process coordination, fluctuations in material quality, and weaknesses in on-site management are prone to triggering quality risks. There is an urgent need to enhance the intrinsic safety and benefits of projects through whole-process control. Focusing on the above situation, this article sorts out key control factors from three aspects: pre-construction design control, dynamic construction process control, and supervision and inspection closure. It diagnoses problems such as the disconnection between design and construction, uneven capabilities of construction teams, lax material quality control, and disordered on-site organization. Subsequently, it proposes countermeasures including strengthening pre-construction quality planning and optimization, systematically improving personnel skills and work standards, establishing a sound material procurement and inspection chain, and perfecting on-site quality supervision and information traceability, aiming to construct an executable and quantifiable quality management system.

1. Introduction

As the process of urban metamorphosis accelerates, the relevancy of municipal investing has changed from quantity expansion to quality and efficiency enhancement. There are objective limits based on peak traffic flows, dense sub-surface pipelines, and steep spanning strata and hydrology differences. This has become a common proposition in the industry and a management pain point, how to ensure quality stability at each process and node. From this, the article selects the key processes and easily out-of-control links in municipal road and bridge construction. It emphasizes pre-design design planning, dynamic construction control and supervision and inspection coordination, aiming to provide the design roadmap & operational points for quality improvement with systems and methods that can be implemented by front-line personnel, narrowing down the "last mile" of standard implementation.

2. Key Control Factors in Quality Management of Municipal Road and Bridge Construction

2.1 Pre-construction Design Control Elements

The design stage, which is at the beginning of quality management, should be fully controlled as "constructible at the source, controllable in the process, and usable in the operation". First of all, based on the expectations for the volume of traffic in future years, geological & hydrological surveys and surrounding existing facilities and pipeline conditions, three design options should be compared and selected to allow clearance checks so that structural system, bridge deck system, foundation type matches up with life-cycle requirements respective to the site constraints. Second, key point best practices and construction drawings should be further refined, clarify allowable tolerances, process interface and inspection batch requirements to avoid on-site secondary interpretation and arbitrary changes. Thirdly, use a design planning checklist containing indicators of material, durability, drainage and protection measures, seismic and thermic effects and the

  DOI: 10.25236/icacel.2025.066

boundary conditions for construction temporary bridges and traffic diversion. At the same time, conduct construction risk assessments and specific demonstrations [1]. Finally, a design change control mechanism and technical verification process should be established for the project to ensure that the original intent of the design does not change during most of the procurement and implementation phases. Since this ensures that quality references for performance, maintenance and test standards are clear, complete and traceable, it is conducive to subsequent dynamic control of good construction practices as well as supervision inspection.

2.2 Dynamic Quality Control during Construction

During construction, it is the quality control that pursues "Mastery in Real Time + Act Before It Goes Out of Control + Do Everything to Ensure there Are No Loose Threads." Understanding process interfaces are what really is the key. The requirements of first piece approval and on site process supervision should be clear for key processes such as surveying & staking out, foundation treatment, formwork systems, steel bar welding etc once they are approved by the process owner which should become a model which comprises sample first and then sign off & on-site process verification. Concrete will be mixed, transported one or more times, poured for placement, vibrated and cured these processes should typically get monitored as a full process. The temperature and strength double curves should be established, the corresponding age and component parts should arrange the monitoring point, and it should be ensured that cracks and voids are avoided. The "layer-by-layer acceptance, thin paving, and sufficient rolling" principle is maintained for the backfilling of subgrade and bridge abutment, while the release criteria are deflection and nuclear density gauge data. Technical disclosures should be-go over and re-estimated and once more checked for parts that are at risk of changes, for example, bearing settings, extension joints and seepage subtleties. We will build a traceability system based on two-dimensional codes from the time of material entry to witness sampling, and then link re-inspection, abnormal batches are immediately isolated. The management of on-site should take early warning threshold management and problem list management with the personnel, time limit and be responsible for rectification of the problems. After the rectification is completed, it should be verified by actual measurement and third-party sampling inspection to ensure that quality deviations are detected early and controlled within allowable limits.

2.3 Full-process Quality Assurance through Supervision and Inspection

Supervision and inspection should penetrate all links from project start to completion, the most essential thing is to establish quality pass levels in advance, and address on-site issues. Prior to construction, it is necessary to carry out drawing and plan verification of personnel and equipment qualifications, identify work stoppage points, key process supervision points on-site supervision as well as witness sampling lists. Construction progress is advanced on the basis of an approach of "first-piece process patrol inspection-concealed work acceptance-stage review": mass production can only proceed after the first piece passes inspection; key inspections are performed on foundation excavation, steel bar nodes, concrete pouring, bridge deck paving, expansion joints and bearing installation; measurements such as flatness-compactness-strength-water permeability coefficient are used to determine whether or not to release work. Double-certification verification of materials and components, batch sampling, isolation of non-conformance items, projects related to load-bearing safety shall be re-inspected. The found deviations can be recorded in the rectification order with defined responsibilities and deadlines, and after re-examination is confirmed to meet the requirements of [2]. To eliminate the information gap, joint reviews involving design, construction and supervision should be conducted for key nodes. Completion quality inspection, the main part is: comprehensive inspections should be conducted to check structural appearance, alignment, durability and load-bearing performance etc.Quality evaluation shall be performed based on data verification and sampling inspection results; delivery maintainability traceability defines whether the project can be delivered.

3. Main Problems in Quality Management of Municipal Road and Bridge Construction

3.1 Disconnection between Design and Construction

In many projects, the disconnect between design and construction is prominent: survey data is not updated in a timely manner, changes in geology, hydrology and surrounding pipeline are not fed back to design outcomes; The design depth is insufficient with Missing detailed construction drawings, node practices and dimensional tolerances; frequent on-site oral explanations; inconsistencies exist between bidding drawings and construction drawings, with deviations in technical conditions, material indicators and measurement rules; formalistic design disclosures exist; unclear construction sequences for key parts of the project parts (such as water diversion of main bridges), temporary structures involved such as cofferdams or silt fences as well as traffic diversion boundaries affect planning during the executing stage; BIM models may fail to match two-dimensional drawings, and clearance or collision issues may only be discovered on site. Long approval chains and unclear communication can slow information transmission, increase costs, cause work stoppages, and create hidden quality risks.

3.2 Uneven Technical Levels of Construction Teams

Instead, as it is often the case in real construction, some teams are technically weak. Many have a poor grasp of surveying and staking out, elevation control, and alignment smoothness; the situation is out of control easily that their first piece may be deviate greatly; they do not master steel bar cutting bend binding, with protection layer thickness/anchorage length/node lap joints simple left-out or overbulging; many lack experience in choosing formwork system/reinforcement calculation, with pure bulging/running/misalignment at formwork area appearing more frequently than desired; for high-precision processes like bridge bearing installation/expansion joint slot treatment/drainage details/issues relating to re-work are common due to unskilled operators with little technique studied well beforehand; improper compaction method used for subgrade and bridge abutment backfilling with no records being kept about water content values/pass log leading to uneven settlement as there are more records lost than recovery in this respect. Weak measurement review awareness is displayed during engineer measuring reveal times/concealed work acceptance so too are data syncing/messages about actual structure on private funding projects afterwards causing delays/both deviation from agreed completion status & also deviations between what was recorded earlier since often information appears before it is printed but then one ends up having discrepancies later when someone realises numbers read different because things get misplaced all while different people run about shouting orders/trying organizing efforts here blindly raising eyebrows whilst others less involved walk around without knowing who should take care next project instead - recurrent leaving gaps between key knowledge at site management level creating big voids caused by personnel turnover/subcontracting complexity (such disconnect leads us ultimately toward dormitory way professional grade sense).

3.3 Non-standard Material Quality Control and Procurement Management

The former relates to arbitrariness of procurement of materials. The definition language of technical terminology in bidding documents is articulated generally with unmarked boundaries explaining on brands and performance causing the cement scale racket to, compatibility in admixtures as poor, incongruence between concrete quality grades leading steel bars to disintegrate even before constructing a multi-storied building. Finally, this causes batch differences and hidden risks, the supply cycle is inconsistent with the project progress, causing frequent on-site replacement. Secondly, the acceptance and inspection of goods on-site is neglectful. Quality assurance certificates and compliance certifications are copied and filled in with low witness sampling proportions, as well as missing re-inspection items. For instance, sand and gravel silt content and soil water content are all important indicators with limited continuous data over the long term. Asphalt, emulsifiers, expansion joint adhesives and bearing rubber physical property control is rough. Some warehouses do not meet the requirements of stacking and moisture-proof and sun-proof conditions, resulting in a decline in material properties during storage. Lastly, there

are incomplete log records of procurement and usagebatch traceability chains that break off on their journey. This type of meter calibration and measuring instrument verification is overdue, on-site batching departs from the design mix proportion. Conditions of technique and downstream scope for old-generation materials are not accurate. The principle of lowest-bid-wins thereby ensures the supply of low-quality and however good materials will be replaced by inferior quality products leading to discrete entity quality with rework and claim disputes.

3.4 Disordered On-site Organization and Management

Heavy on one hand, out in a crowded plan: disorganization through system activity. Weekly Plan vs Daily Plan disconnected, Cross-operations go without temporal and spatial separation. Site layout is arbitrary and material stacking intrudes on walkways; mechanical access is random, resulting in queuing for key functions; lifting pouring and transportation operations interfere with one another. Repeated revisions of temporary power and temporary roads resulting in the potential for impacts on control of alignment or processes [3]. Construction progress: concealed work acceptance are often squeezed. In contrast, job responsibilities are less well-defined, so construction, testing, measurement and data people function autonomously. Sign-off procedures are sometimes slow and circular, on-site supervision at patrol inspection records were stale. Weak arrangements for night and holiday duty, no follow up on closure of problems. Subcontractor and labor teams communication is fragmented, with safety checklists and finished product protection underperforming. During the rainy and high-temperature seasons, construction arrangements get adjusted arbitrarily causing overlapping rework on one hand while quality fluctuates which gets concentratedly exposed in mega blocks before key milestones.

4. Countermeasures to Improve Quality Management of Municipal Road and Bridge Construction

4.1 Strengthen Pre-construction Design Quality Control

Constructibility, manageability, and maintainability should be incorporated throughout the entire process to enhance quality control of pre-construction design. Textile investigation: Improve surveying and current situation investigations and advance essential data layering on soft soil, groundwater, existing pipelines, traffic organization accompany simultaneous multi-option technical and cost comparisons; Clarify integrated limits of foundation types/structural systems /durability indicators. Second, strengthen the detailed design of construction nodes, dimensions and tolerances, as well as on inspection lots and give restrictions on template, scaffold system, temporary structures and traffic diversion. Model for collision checks and verification on clearance to help reveal inter-collision in advance so that changes can be made within the drawings. Lastly, set up cross-domain joint reviews and change control paths, define point where work can be halted and when it needs to be signed off, ensure that design intent is communicated consistently to procurement and build sites, deliver easy usable references to the team needing these outputs for future quality-monitors and risk-predictors.

4.2 Improve Construction Personnel Technical Skills and Qualities

Firstly, gather courseware and operational points around job-related items like surveying and staking out, steel bar connections, formwork systems, concrete temperature control and details of working on bridge decks. Put entry examinations and certification on most essential processes to make sure that standards are actually executed by people. Next, create a mentor-apprentice pairing and group competitions; set quantitative benchmarks such as the quality of samples sent to us, actual measurements taken, rework rates in doing analyses, and consistency between data sets; tie results to price points or awards/denied access for sub-contractors all can incentivize personnel through comparative motivation. Thirdly, for an error-prone process (e.g. bearing installation, expansion joint treatment, drainage details backfill compaction), a rolling review of the 'problem photo library + problem collection' to form visual warnings and retraining lists; By the same token,

live synchronisation of technical disclosures, on-site supervision records and test data, will reduce gaps in information by making on-site processes for measurement review and concealed work acceptance more robust. Finally, set up a fast link mechanism for mobile personnel and seasonal construction secondary education training, integrated explanation of safety-quality-process interfaces, so that the team can uphold stable operational standards and quality output in different working conditions.

4.3 Standardize Material Procurement and Quality Supervision Systems

In order to realize a closed loop conversion from the source part of material procurement and quality supervision systems to technical standards, supply chain management, and on-site verification should be closely linked. For key materials such as cement, steel bars, admixtures, asphalt, expansion devices and bearings, performance indicators, test methods and acceptance frequencies should be defined clearly, and the functions of compatibility, durability and environmental adaptability are not only described vaguely in procurement technical conditions or contract terms. Optimize Supplier Access and Dynamic Assessment Bid weights based on 3 years of supplier performance results, capacity real-time pass rate, delivery stability assessment, price reasonable evaluation and establish black and white lists + early warning mechanism. Incorporating a three-in-one system for witness sampling, re-inspection and sample retention of incoming batches; achieving account-based and trend-based clue management of indicators such as sand and gravel silt content, water content grade curves, steel bar mechanical properties, etc., automatically triggering isolation in case of abnormality, immediate inspection. Configure storage areas as per classification, ventilation, moisture-proof, sun-proof and pollution prevention requirements, set first in first out and expiration date management; calibrate measuring instruments on time, cooperate with automatic weighing and two-dimensional code traceability to realize accurate batching and traceability [4].

4.4 Improve On-site Construction Quality Supervision Mechanisms

Establish first-piece chapter and sample-led measures, set on-site supervision points and work stoppage points, surround key processes such as surveying and laying out, foundation treatment, steel bar nodes, concrete pouring, bridge deck paving, and backfill compaction. Supervisors shall be conducting daily patrols concurrently with special spot checks, actual measurements should include flatness, compactness, strength, alignment and water permeability indicators and results must be documented in ledgers to serve as trend charts. Implement strict witness sampling, re-inspection, and sample retention while using two-dimensional code traceability for material batches, equipment metering and construction logs to ensure data consistency with the actual structure. Order write-up orders for issues and defects, with specific obligations, deadlines, and re-inspection methods, and re-release after passing the inspection again. For key nodes, organize multi-party reviews and technical verifications to control the length of change chain and information lag: keep design intentions unchanged without postponing processes. Before the project completion, carry out thorough appearance, dimensional and load or functional testing along with traceable quality records.

5. Conclusion

In summary, the quality management of municipal road and bridge projects must run through the levels (source, process and result) to form a closed-loop chain that can be traced and measured. The use of design as master to unify constructability and durability goals, construction as core to capture key processes and interface details, supervision/ inspection as safeguard for support quality baseline by data and system. Also bring together personnel ability, material control, and on the place of job organization, and get rid of information transmission bottleneck through means that effectiveness in change command to make sure consistency among usual fact and structure. Stabilise the project quality baseline and enhance the safety, durability and operational performance of urban transportation infrastructure by means of sample-led approaches, risk pre-emption and continuous

improvement.

References

[1] Xie Keke. Key Control Factors and Countermeasures in Quality Management of Municipal Road and Bridge Construction [J]. Doors & Windows, 2025(6): 142-144.

[2] Wu Min. Research on Quality Control and Management Strategies in Municipal Road and Bridge Engineering Construction [J]. Modern Decoration, 2025, 614(15): 184-186.

[3] Jiang Liqing. Research on the Application and Quality Control of Key Technologies in Municipal Road and Bridge Construction [J]. Real Estate Guide, 2022(11): 91-93.

[4] Tian Duoshan. A Brief Discussion on the Application and Quality Control of Key Technologies in Municipal Road and Bridge Construction [J]. Modern Property, 2021(14): 156.