Research on the Causes and Preventive Measures of Common Quality Issues in Municipal Road and Bridge Construction

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Abstract: Municipal road and bridge engineering holds a core position in urban infrastructure construction, with its construction quality directly linked to public travel safety and the operational efficiency of urban functions. However, during the construction phase of municipal road and bridge projects, influenced by factors such as techniques and management levels, common quality issues like settlement, cracking, and structural instability arise. These problems shorten the project's service life and increase long-term maintenance costs. This paper analyzes the importance of ensuring construction quality for municipal roads and bridges, examines common quality issues and their causes, and proposes reasonable preventive measures. These measures include strengthening hydrogeological surveys and foundation treatment, optimizing concrete construction techniques, enhancing anti-corrosion treatment, and meticulously implementing the installation of ancillary facilities and joint treatment. The aim is to provide a reference for the development of urban infrastructure construction.

1. Introduction

While municipal road and bridge engineering is flourishing, construction quality issues are becoming increasingly prominent. Problems such as pavement cracks and bridge approach bump pose threats to the safety of passing vehicles and pedestrians and increase long-term maintenance costs for projects. Therefore, the construction sector is actively exploring these common quality issues and their specific causes to propose reliable and effective preventive measures. This effort promotes the steady improvement of construction quality for municipal roads and bridges, holding significant practical importance for the sustainable development of modern urban construction.

2. The Importance of Ensuring Construction Quality for Municipal Roads and Bridges

2.1 Enhancing Urban Operational Efficiency

Municipal road and bridge engineering forms the core network of urban transportation, and its construction quality directly impacts urban operational efficiency. Ensuring high construction quality improves the rationality of bridge structural design, guaranteeing fast and stable passage for vehicles. Furthermore, good construction quality reduces long-term maintenance costs, avoiding resource waste and traffic disruptions caused by frequent repairs, thereby creating favorable conditions for stable urban traffic operation.

2.2 Shaping the Urban Image

High-quality municipal road and bridge projects, characterized by wide, smooth roads and sturdy bridges, create a safe and reliable environment for public travel, fostering trust and reliance on the city among its residents. Simultaneously, unique bridge designs can integrate with the surrounding environment, becoming iconic structures in modern urban development and bringing significant fame and reputation to the city.

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3.Analysis of Common Quality Issues and Their Causes in Municipal Road and Bridge Construction

3.1 Uneven Subgrade Settlement

Uneven subgrade settlement is a common and highly detrimental quality issue in municipal road and bridge construction. It leads to pavement distress such as cracks, potholes, and undulations, affecting driving comfort and safety, and threatening the service life of the structure [1]. Differences in geological conditions are a primary factor. Soil properties vary across different sections, leading to significant differences in physical and mechanical performance. Soft soil, with characteristics like high compressibility and low strength, is prone to substantial settlement under the weight of the structure and traffic loads. Expansive soil swells upon water absorption and shrinks upon drying, causing repeated volume changes in the subgrade and triggering uneven settlement. Unqualified fill material may fail to achieve the required compaction density. Excessive layer thickness during filling or insufficient compaction equipment tonnage can leave voids or uneven compaction within the fill, creating weak areas that undergo differential settlement under prolonged traffic loads. As bridge structures are rigid bodies with minimal self-settlement, while adjacent embankments are flexible, narrow backfill areas behind abutments make compaction difficult, often leading to insufficient density and significant "bridge approach bump" issues.

3.2 Pavement Cracking

Pavement cracking manifests in various forms such as transverse, longitudinal, and mesh cracks. Cracking compromises pavement smoothness and aesthetics, reduces load-bearing capacity, and poses safety hazards. The causes are complex. Material-wise, unqualified cement soundness can lead to uneven volume changes during hardening, causing cracking. Asphalt materials not meeting penetration or softening point requirements can crack under extreme temperatures. Construction-wise, insufficient compaction of the base course can lead to settlement under repeated traffic loads, subsequently cracking the surface layer. Inadequate quality control is also a direct cause. Discontinuous paving, low paving temperatures, insufficient compaction passes, or inadequate density can create weak planes within the surface layer, prone to cracking. Improper handling of daily construction cold joints can also lead to longitudinal cracks.

3.3 Drainage System Failure

Drainage system failure is a common quality issue, mainly manifesting as severe water ponding and poor drainage. During rainfall, large puddles form in low-lying road areas, impeding traffic and threatening vehicle safety, potentially causing skidding or loss of control. Unreasonable drainage pipe design, failing to consider local rainfall, topography, etc., can result in insufficient pipe diameter. Improper pipe slopes can cause siltation (if too flat) or pipe wall erosion (if too steep). After trench excavation, insufficient bearing capacity of the base or failure to compact and lay bedding according to specifications can lead to uneven settlement after pipe installation, causing joint cracks or pipe breaks, paralyzing the drainage system. Using substandard pipes or manhole covers directly reduces system durability and reliability. Construction debris like mortar and soil entering unsealed pipe openings can cause permanent blockages, creating significant hidden dangers for future operation and maintenance.

3.4 Defects in Ancillary Facility Installation

Ancillary facilities are crucial for ensuring the functional integrity and safety of roads and bridges, and their installation quality directly affects overall project quality. However, installation defects frequently occur. Firstly, drainage facility defects, such as grating height exceeding tolerance, cause poor drainage or vehicular bumpiness. Secondly, insufficient process control, like not using high-precision equipment (e.g., total stations) for positioning, or lack of symmetrical vibration during concrete pouring, leads to embedded part displacement. Thirdly, poor coordination with the main structure contractor regarding construction sequence, inaccurate timing for embedded part installation, and lack of synchronous protection during paving cause damage to finished products. Additionally, some construction personnel lack responsibility, prioritizing progress over detail quality, failing to identify and correct defects promptly, allowing minor issues to become persistent problems.

3.5 Joint Treatment Problems

Joint treatment is a critical link in construction. Improper handling severely affectsengineering quality and performance. After projects are put into use, concrete at joints can spall or break away, causing structural discontinuity and reducing load-bearing capacity. Water seeping through joints erodes internal reinforcement, affecting durability. Substandard joint materials (sealants, fillers) with inadequate adhesion, elasticity, or durability are a primary cause. Under temperature changes and traffic loads, they age, crack, and detach, leading to joint failure. Inadequate joint preparation, like not thoroughly cleaning debris and laitance, affects bonding. Opening joints to traffic or heavy equipment before sufficient strength gain causes early damage.

4.Preventive Measures for Common Quality Issues in Municipal Road and Bridge Construction

4.1 Strengthening Hydrogeological Survey and Foundation Treatment

A key measure for preventing uneven settlement is conducting precise hydrogeological surveys [2]. Before construction, use comprehensive methods like drilling, in-situ testing, and geophysical prospecting to identify stratum distribution, weak interlayer locations, groundwater dynamics, and soil permeability. Install long-term observation wells in areas with fluctuating water tables and build 3D geological models for quantitative stress-strain analysis. Implement zonal treatment based on survey results: vacuum preloading combined with surcharge preloading for soft soil; cement mixing pile composite foundations for deep silt layers. Investigate historical highest water levels and annual fluctuations to analyze potential adverse effects on subgrade soil, implementing targeted foundation treatments to eliminate settlement risks. Design comprehensive water management systems based on hydrogeological data. Use water-stable fill materials and strictly control compaction in areas susceptible to water level changes.

4.2 Optimizing Concrete Construction Techniques

To address pavement cracking, optimize concrete techniques and strictly control raw material quality. Use cement with low heat of hydration and shrinkage, rigorously checking its soundness and strength. Control aggregate silt content ($\leq 3\%$ for fine, $\leq 1\%$ for coarse) to reduce shrinkage cracks. Minimize cement content (while meeting strength requirements) to lower heat of hydration. Incorporate mineral admixtures like fly ash or slag powder to improve workability and reduce heat, inhibiting cracking. For mass concrete, use cooling pipes or embedded temperature sensors to control the internal-external temperature differential. Use chilled mixing water in summer and thermal protection measures in winter. During curing, keep surfaces moist using geotextile covers or curing compounds to prevent plastic shrinkage cracks. Introduce smart monitoring technologies to track temperature and strain, using data analysis to predict cracking risks and dynamically adjust process parameters.

4.3 Enhancing Anti-Corrosion Treatment

Establish a coordinated anti-corrosion and drainage control system from materials, processes, to monitoring. Establish material corrosion resistance rating standards for different environments. Prefer HDPE double-wall corrugated pipes or epoxy-coated steel pipes for drainage [3]. Incorporate rust inhibitors in concrete to stabilize the passive film on rebar; use silane impregnation to create a hydrophobic layer, reducing chloride ion penetration. Validate all material durability through simulated corrosion tests matching project conditions. During construction, use high-pressure water jetting for trench cleaning, control base levelness to avoid water accumulation and corrosion. Ensure drainpipes and downpipes are securely installed, using high-performance sealants or rubber gaskets for flexible connections to prevent joint cracking from vibration. Post-construction, establish a regular inspection and maintenance regime. Check drainage systems for blockages before/after flood seasons, and inspect metal component coatings for blistering or peeling. Perform prompt local repairs and recoating upon damage to prevent defect expansion, effectively extending the service life of drainage systems.

4.4 Meticulous Implementation of Ancillary Facility Installation

Implement a full-chain control strategy for ancillary facilities covering technical disclosure, process control, and acceptance closure. Strictly follow designs and specifications, developing specific construction plans. Specify the use of anti-settlement manhole frames and concrete encasement to control grating height difference within ±2mm. Clean the pavement before marking, use high-adhesion reflective paint, and ensure line straightness with laser positioning instruments. For embedded parts, use anti-corrosion materials, verify dimensions, elevation, and levelness before placement, and use dedicated positioning molds. Monitor during concrete pouring to prevent displacement. For independent foundations (e.g., lights, signs), strictly follow design reinforcement and concrete grade, reserve drain holes, and ensure consistent top elevation. Implement a three-level inspection system (team self-check, dedicated inspector, supervisor acceptance) for each process, with signed records archived. Apply special corrective closed-loop management for frequent quality issues.

4.5 Construction and Expansion Joint Treatment

Strictly follow design requirements and standards for joint placement, avoiding key structural stress areas [4]. For roads, place longitudinal construction joints near lane lines. For bridges, leave reasonable gaps between caps/piers and girders. Before joint work, scabbold old concrete surfaces to remove laitance and loose particles, exposing aggregate (depth 3-5mm, spacing ≤5cm). Clean the interface with high-pressure water until free of dust and oil. Apply cement-based bonding agents uniformly before new concrete placement. Use shrinkage-compensating concrete or high-strength grout for joint filling, determining the optimal mix through trials. Consider adding polypropylene or steel fibers to improve crack resistance, ensuring workability and density. Control layer thickness during placement, use internal vibrators for adequate compaction to fill joints completely, avoiding voids and honeycombing. Use non-destructive testing post-construction to check internal joint quality. Perform grouting repairs for defects promptly. Maintain or replace aged/damaged sealants to extend service life.

5. Conclusion

In summary, high-quality municipal road and bridge construction plays a vital role in enhancing urban operational efficiency, ensuring public travel safety, and shaping the urban image. However, quality management is an incremental process requiring continuous exploration of strategies to prevent common issues. Therefore, construction departments should conduct thorough hydrogeological surveys, optimize concrete construction techniques, meticulously install ancillary facilities, and rigorously inspect joint treatments to promote the high-quality development of municipal road and bridge engineering.

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