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Crack Prevention and Management Strategies in Bridge Engineering Construction

Yanzhen Lin*

Binzhou Municipal Public Development Service Center, Binzhou 256600, China

***Corresponding author:** Yanzhen Lin, linyanzhen0114@163.com

Abstract: Cracking during construction is a common occurrence in modern bridge engineering that can directly impact the overall safety of the bridge. Therefore, it is essential to focus on preventing and controlling cracks. As the construction technology for bridge engineering has evolved, the internal quality of construction has significantly improved. However, the appearance quality remains a crucial factor that reflects the technical expertise of a construction company. Therefore, minimizing cracks and improving the appearance quality of concrete are critical issues that require the attention of construction units, supervision departments, and construction companies. This article will analyze the causes of cracking and suggest corresponding prevention and treatment methods.

Keywords: Bridge engineering; Engineering quality; Quality management

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1. Introduction

Cracks are common in bridge construction and can occur for several reasons. The primary cause is often related to material control in highway construction. Other factors, such as weather and construction technology, can also contribute to issues with bridge projects. However, cracks can be significantly reduced if construction specifications are strictly followed during the construction process. When a crack occurs, effective remedial measures should be taken to minimize the damage they cause to the road and bridge.

2. Concrete cracks

As an important raw material for civil construction, concrete has good integrity, extensibility, high strength, moldability, and fire resistance, and it also posses excellent earthquake and explosion resistance. It has good radiation and vibration resistance, making it suitable for protecting structures [1]. However, changes in the external environment (such as temperature, load, etc.) will greatly impact the hardening process of concrete. Initial stress, tensile stress, or shear stress will be generated in the concrete, which leads to aggregation. As a result, cracks may appear on the bonding surface with the cement stone, severely affecting the quality of the project.

3. Causes of concrete cracks in bridges

3.1. Causes of subsidence

If the foundation soil is not good or the density of the backfill layer is too low, rain has soaked it for a long time, resulting in uneven settlement and cracking problems. Because the stiffness of the formwork does not meet the specifications, the lower part of the supports is loose, or the distance between the supports is too large, which can easily cause settlement. During winter, the frozen soil thaws and causes settlement, leading to cracks in concrete structures.

3.2. Shrinkage and frost heaving

Frost heave and shrinkage are the primary causes of concrete cracking. Due to the material's physical properties, its volume increases. At this time, there is a contradiction between its volume and strength, and cracks are prone to occur [2].

3.3. Temperature

The appearance of cracks is attributed to the high outdoor temperatures. In such conditions, heat accumulates inside the concrete and struggles to dissipate, leading to differential cooling rates between the exterior and interior. While heat dissipates rapidly from the outer surface, the internal temperature remains high, causing a significant temperature disparity [3]. This leads to the formation of large compressive stress, coupled with some tensile stress on the exterior. In the early stages, concrete's tensile strength is poor, making it susceptible to temperature-induced cracks once temperatures reach a certain threshold. Additionally, concrete undergoes thermal expansion and contraction after pouring, gradually hardening as temperatures drop. This process causes the volume to decrease, contributing to crack formation.

3.4. Hazards of cracks in bridge projects

Since the main component of the bridge is concrete, cracks during the construction process will significantly impact the structure and safety of the entire bridge. Besides, the bridge is exposed to rain and snow. Rainwater seeps into the bridge's interior through gaps, causing the steel bars in the concrete to corrode, thereby reducing the load-bearing capacity of the bridge. Once the pile foundation cracks, the entire bridge might collapse. Steel bars and concrete structures serve as the primary load-bearing components of bridges, and when cracks develop, they gradually widen under the bridge's weight, compromising the overall quality of the structure. If cracks are left untreated in bridge projects, internal corrosion within the concrete accelerates, leading to eventual breakage of the steel bars and compromising structural stability. Furthermore, cracks during the construction process not only impact project quality but also extend project timelines.

4. Crack prevention and management strategies in bridge engineering construction

4.1. Quality management of construction materials

The quality of construction steel significantly impacts the safety of bridge projects, necessitating rigorous control measures to prevent cracking and ensure safety. During material procurement, purchasing personnel must possess thorough knowledge of available materials, exercise quality control, compare suppliers, and choose those offering cost-effective advantages. Upon arrival at the construction site, materials undergo inspection and acceptance to ensure compliance with construction standards. Unqualified materials are prohibited from entering the site. Failure to meet concrete quality standards can result in cracking during bridge

construction. Therefore, cement hydration heat testing is conducted prior to construction to verify compliance. Additionally, concrete quality and slump are assessed before construction, with strict adherence to ensuring water is not added during the construction process.

4.2. Optimizing construction design

Before construction, designers must survey the project site to understand the transportation routes, rock formation characteristics, hydrogeological conditions, topography, etc. of the construction site and design the construction plan using building information technology [4]. The construction plan must be tailored to the specific conditions of the project to enhance project quality and minimize cracking rates. This involves engaging experts to conduct thorough economic and technical evaluations of each plan, selecting the one that not only guarantees project quality but also reduces construction costs, thereby enhancing overall construction efficiency.

4.3. Strengthening the management of construction materials

Building materials play a significant role in concrete structure cracking, highlighting the importance of careful material selection and strengthened construction management. Firstly, specifications, models, and conditions of selected materials should be clarified based on project requirements and measured data, with reasonable selections made based on experimental results. Secondly, random inspections of raw materials are necessary to ensure they meet design requirements; stone particle sizes and asphalt materials must meet construction needs to mitigate cracking risks from the outset.

4.4. Controlling construction temperature

Selecting construction materials and controlling surrounding temperatures are critical aspects of bridge construction. High temperatures can lead to rapid moisture evaporation in concrete, prolonging hardening time and potentially causing condensation issues. Therefore, minimizing sun exposure during construction is essential. Additionally, proper concrete maintenance is crucial, including covering the surface with a moisturizing film to reduce temperature differences between internal and external environments. Regular watering and maintenance during the initial construction days gradually decrease over time. Special concrete characteristics may require specific maintenance [5]. Effective inspection of concrete strength during curing and stress strength after construction is necessary to meet design quality requirements and improve construction quality. When planning road and bridge projects, construction companies should consider climate, and environmental factors, and select appropriate raw materials and construction technology. Adjusting concrete pouring timing, speed, and curing methods according to environmental characteristics and climate conditions ensures project quality.

4.5. Understanding the technical processes involved

To mitigate cracks during construction, strict regulation of technical specifications and procedures is essential in engineering practice. This involves implementing standardized procedures to ensure the rationality of the construction process. Quality awareness among construction employees must be enhanced through comprehensive pre-job education and training, emphasizing adherence to determined construction procedures without unauthorized changes or material substitutions. Active implementation of side station monitoring systems, particularly in key projects and processes, helps promptly identify and correct illegal or improper operations, minimizing safety risks. Strengthened supervision and establishment of an accountability system are crucial during construction stages prone to cracks, encouraging workers' enthusiasm and sense of responsibility.

Additionally, addressing existing cracks promptly is vital to prevent further deterioration. Construction workers must report cracks promptly, determine their cause, and implement appropriate countermeasures, such as caulking, sealing, grouting, surface repair, electrochemical protection, and reinforcement techniques, to effectively strengthen the bridge without compromising its overall bearing capacity [6].

4.6. Load control

A reasonable construction plan must be formulated during the bridge construction process to ensure project quality. The designer must understand the site conditions and perform reasonable calculations and load designs during the design stage. When factoring in load weight, a comprehensive analysis of the entire process post-completion is essential. Site-specific conditions such as temperature and location must be considered to prevent local loads from surpassing standards. This can be achieved through strategic load distribution arrangements, establishing various reliable solutions. These solutions should undergo thorough evaluation from multiple perspectives to verify their feasibility and minimize the risk of cracking, thereby enhancing the overall quality of the bridge.

4.7. Pre-construction personnel training

Improving the skills of construction workers is crucial, especially considering many come from remote areas with limited training opportunities. Prior to deployment, comprehensive training should be provided to ensure proficiency in engineering practices. Site managers should employ teaching methods to demonstrate tasks, enhancing safety awareness and responsibility among workers. Tasks should be assigned according to each individual's abilities to ensure optimal performance. For instance, concrete vibrators must be adept at their craft. Upon completion, workers should undergo evaluation, allowing only qualified individuals on-site. Implementing a robust reward and punishment system will provide material incentives, thereby promoting better construction quality and minimizing cracks in bridge construction.

4.8. Post-construction maintenance

After the bridge construction is completed, subsequent maintenance must be carried out. Specifically, designated personnel should promptly cover and water the concrete to prevent rapid heat loss from the surface and address any cracks swiftly to prevent further damage to the entire bridge. Furthermore, thorough inspections of the bridge's drainage system are imperative during the maintenance phase to prevent water accumulation on the bridge deck, which could compromise the overall structure.

5. Conclusion

In summary, cracking is a common issue in bridge construction, impacting both quality and structural integrity. Addressing its root causes requires tailored solutions and proactive prevention measures during construction. Swift action is essential upon detection to prevent further escalation. Strengthening construction teams and prioritizing ongoing maintenance are crucial steps in ensuring bridge construction quality and mitigating the impact of cracks.

Disclosure statement

The author declares no conflict of interest.

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