Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Phased Construction Bridges: Monitoring and Analysis for Traffic-Induced Vibration

Research Objectives

Determine the amplitude, frequency, and duration of traffic-induced vibration that results in premature deterioration of concrete bridge decks in phased construction and identified methods for mitigating its effects.

Research Benefits

As a result of this project, recommendations were made to mitigate premature deterioration of concrete bridge decks poured during phased construction. When implemented, this will enhance the durability of Nebraska bridges reducing costs associated with deck maintenance, rehabilitation, and replacement. Furthermore, extensive cracking of phased construction bridge decks is a nationwide issue; and recommendations developed in this project have the potential to impact construction practice around the United States and abroad.

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Background

Due to the current state of deteriorating infrastructure in the region and country, the number of bridges in the state and in the country in need of replacement is expected to increase. However, the complete closure of a traffic route to allow for the construction of a new bridge is often not feasible-particularly in rural Nebraska, in which truck traffic is limited to few routes and is critical to the economic vitality of the state. To address this need and reduce detours, phased (staged) construction has become a very prevalent practice for bridge replacement, which allows the bridge to remain partially open to traffic throughout construction. While phased construction can be interpreted as a very broad term, herein it is defined as the situation where one segment of the bridge is constructed adjacent to an existing segment. Typically, the number of traffic lanes is reduced to allow for partial demolition of the bridge. Then, a new segment of the bridge is constructed-termed the first phase. Once traffic is re-routed to the new segment, the remaining bridge is demolished and replaced -the new construction termed he second phase. In most situations, rebar extends from the first phase deck and is spliced to the second phase deck reinforcement prior to pouring of the deck.

This project directly addressed this gap in knowledge by measuring existing levels of traffic-induced vibration in the field and directly implementing varying levels of this vibration in a laboratory experiment. Results of these experiments provide clear guidance on how to mitigate the harmful impacts of traffic-induced vibration and enhance the durability of phased construction bridge decks.

Conclusion

Phased construction is a common technique utilized to allow bridges to remain partially open to traffic throughout the construction process. The segment of the bridge deck that is constructed second cures under the effect of traffic-induced vibration transmitted from the adjacent bridge-deck segment, which is open to traffic. However, subjecting bridge decks to traffic-induced vibration during early-age curing raises concerns about the durability of the decks. The primary goal of this study is to generate a fundamental understanding of the transmission of traffic-induced vibration, the extent of degradation on phased construction bridge decks, and the impact of potential mitigation measures. In this study, the response of two phased-construction bridges in Nebraska were monitored before, during, and after the second stage of phased construction. Within 6-7 hours of the second-phase pour, the two phases of the bridges converged dynamically and began to behave as a single structure. To further understand this behavior, an experimental program was executed incorporating two phased-construction specimens and one which was constructed in a non-phased manner. The phased-constructed specimens were subjected to simulated traffic-induced vibration protocols for 0 – 12 and 7 – 12 hours from the start of the pour. Within hours of the pour, significant cracks were observed in the specimen subjected to traffic for 0 –12 hours. While cracks were similarly noted for the other phased specimen, the cracks were much less extensive and did not exceed hairline widths. No cracks were observed for the non-phased specimen. Upon further evaluation, it was concluded that the critical time window of 6-7 hours during which traffic-induced vibration has the most significant impact on deck cracking corresponds to the concrete setting time. Therefore, it is recommended that phased construction bridges close for the duration of the concrete setting time to reduce premature deterioration.

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NDOT Recommendations Based Of Research Project

Based on the research no recommendation can be made that would guarantee enhanced performance. Further testing and research are needed to provide such recommendation.

Further testing – for example, the condition of no truck traffic – would require more research to set the minimum vibration threshold. Field monitoring can provide more information and allow the researchers to further define thresholds. Monitoring can take place using accelerometers – physical sensors attached to a bridge on one line (cross-section).

For application purposes for this research, the Department could select a project and possibly work with a district to close to traffic for 6-7 hours and monitor. Either for short or long-term monitoring is possible with two choices:

1. Close for 6-7 hours. If that is not possible, then:
2. Implement other vibration mitigation techniques, by reducing the speed or reducing speed of all traffic and prohibiting truck traffic during the monitoring timeframe.

The selected project can provide recommendations relating to the construction practice for phased construction bridges to reduce premature deterioration associated with traffic-induced vibration. These recommendations may include traffic restrictions, speed reductions, placement of heavy equipment, and other mitigation measures.

- *As provided by Fouad Jaber, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 2

Level 2: Applied Research/Proof Concept

-Research/Technology developed. Integration of components needed for proof of concept.

Technology Transfer

Conference Presentations (with Corresponding Papers):

- Alkady, K., Wittich, C.E., Wood, R.L., and Morcous, G. (2022). Phased-construction bridges: field monitoring of traffic-induced vibration and large-scale experimental testing. 11th International Conference on Short and Medium Span Bridges, Toronto, Ontario, July.
- Alkady, K., Wittich, C.E., Wood, R.L., and Morcous, G. (2022). System identification of a highway bridge undergoing phased construction. 8th World Conference on Structural Control and Monitoring. Orlando, FL, June.

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