Implementation of the Negative Moment Reinforcing Detail Recommendations

tech transfer summary

This study confirmed that current design approaches for the amount of longitudinal reinforcement in pre-stressed concrete girder bridges may be overly conservative, and it identified future research directions related to resisting negative moment and implementation of negative reinforcing steel.

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RESEARCH PROJECT TITLE
Implementation of the Negative Moment Reinforcing Detail Recommendations

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Research Objective

The main objective of this research was to evaluate the effect of different amounts of longitudinal reinforcement (b2 bars) on resisting the negative moment over the pier on a continuous prestressed concrete girder bridge when it is subject to the live load-generated moment and secondary moments.

Background

Pre-stressed concrete girder bridges have historically been designed with negative moment reinforcement in order to resist loads after full continuity is achieved. It is common practice to put additional b2 bars over intermediate supports to resist negative moment induced by the superimposed dead loads and live loads on bridges.

The Iowa Department of Transportation (DOT) Office of Bridges and Structures Bridge Design Manual specifically calls for additional longitudinal, so called b2, bars for resistance to negative moments caused by super-imposed dead loads and live loads.

Gauge installation for live load testing on the new County Road E-57 bridge over I-35 in 2017

Problem Statement

Little research has been conducted on the performance of and need for the additional negative reinforcing steel. Requirements for the termination of the additional negative moment reinforcing steel have largely been based on engineering judgement, previous performance, and existing practice. These requirements also vary from state to state.

Additionally, work for the Federal Highway Administration (FHWA) has shown that it is possible to have secondary positive moments that offset the negative moments experienced over piers, thus resulting in no negative moment at all. These contradicting viewpoints served as the motivation behind this investigation and the one before this for the Iowa DOT policy on b2 reinforcement.

Previous Research Summary

The previous study involved the live load testing of a number of bridges, with the results used to calibrate finite element models (FEMs). The finite element results suggested that the transverse field cracks over the pier and at 1/8 of the span length were mainly due to deck shrinkage (Phares et al. 2015). In addition, it was concluded that secondary moments affect the behavior in the negative moment region.

The results of this previously funded research were recommended for implementation such that further evaluations could be completed to confirm the findings and result in the development of updated requirements for negative moment reinforcement in multi-span pre-stressed concrete beam bridges.

Current Research Summary

To achieve the objective of this research, a live load field test was performed on a bridge designed with different amounts of b2 bars to allow for comparison of the varying levels of negative moment reinforcement present. Both current b2 amounts and proposed reduced amounts were investigated by conducting the field test and an analytical study. The negative moments that were studied in this research included both live load generated moment and secondary generated moments.

Research Description

Several tasks were performed in close communication with a technical advisory committee (TAC) that was developed for the project. The main tasks included the following:

- Literature review
- Field test of County Road E-57 bridge over I-35
- Analytical study on the effect of secondary moment

Live load testing the County Road E-57 bridge over I-35

At the beginning of the research, a yet-to-be-constructed bridge on E-57 over I-35 that was designed with different amounts of b2 bar in the deck over each pier was selected and instrumented during bridge construction. This would allow for the comparison of the behavior of cross-sections with varying amounts of negative reinforcement present to help determine what requirements are necessary in the negative moment region of pre-stressed concrete girder bridges.

The live load field test was performed after the deck concrete gained enough strength, and the test was repeated every 12 months to experimentally investigate the performance of the b2 bars regarding resistance of the negative moment due to live loads.

A full-scale FEM was developed and validated against the field-collected data to analytically study the b2 bar performance when subjected to live loads. The effectiveness of the b2 bar at resisting the negative moment induced by long-term secondary moments was evaluated utilizing an analytical approach by calculating the time-dependent secondary moment using mRESTRAINT software and loading the maximum negative moment on the small-scale FEM. The small-scale FEM was developed utilizing the same approach as that used on the full-scale FEM.

Key Findings

- The negative moment induced by the live load or secondary moment does exist through the service life of the bridge. The negative moment induced by the secondary moment alone could be sufficient to generate cracks in the deck, especially when a very old girder is used.
- The additional longitudinal reinforcing steel b2 bar provides minimal effect on resisting the negative moment prior to the formation of deck cracking, regardless of whether the negative moment is induced by either the live load or the secondary moment.

- Under service level design, b2 reinforcing steel does not appear to be necessary, because it provides a minimal contribution to resisting the negative moment prior to the formation of deck cracks. However, as b2 bars are currently designed for the strength level based on the live load, it may be necessary to include the secondary moment in the design.
- The high differential shrinkage rate between the fresh deck concrete and the girder concrete is the main source of negative moment over the supports. Negative moment over the pier is induced by the shrinkage of the deck concrete. Girder creep and shrinkage reduce the negative moment (over the pier).
- The magnitude of secondary moment is highly influenced by the time when the continuity is established. The negative moment (in the secondary moment) was induced only when the continuity was made at an older girder concrete age.
- Different percentages of b2 reinforcement over each pier shows no significant effect on reducing the deck top strain before crack initiation.

Conclusions/Implementation Readiness and Benefits

- The current Iowa DOT design approach determines the b2 bar requirement for the strength level based on the live load, while it may be necessary to include the secondary moment in the design.
- Current design approaches for the amount of b2 bars may be overly conservative.
- To reduce/eliminate the negative moment (as part of the secondary moment), two strategies could be adopted: 1) place the deck concrete (or establish the continuity) at a young girder concrete age and 2) control the deck concrete shrinkage by using shrinkage compensating concrete.

Recommendations for Future Research

Based on the findings of this research, the following recommendations for future research directions related to resisting negative moment and implementation of negative reinforcing steel emerged:

- Since the negative moment predicted in this research is mainly through the use of the mRESTRAINT software, additional research should be conducted to validate the results. The predicted negative moment could be validated by using the data collected from long-term monitoring on a newly constructed continuous multi-span bridge, which captures the structural behavior beginning at construction.
- It is clear that the negative moment (as part of the secondary moment) is greatly impacted by the material properties of the deck and girder concrete, the girder age when continuity was established, etc. Additional research activities could be conducted to estimate the amount of negative moment (as part of secondary moment) for continuous bridges with different numbers of spans and span lengths. The magnitude of the negative moment could be calculated with different combinations of deck and girder concrete properties and different girder ages when the continuity was made. The estimated negative moment could be presented in an interaction diagram and could be easily read by the design or field engineers to incorporate into current design methods.

Reference

Phares, B., S. Jayathilaka, and L. Greimann. 2015. *Investigation of Negative Moment Reinforcing in Bridge Decks*. Bridge Engineering Center, Iowa State University, Ames, IA. **https://intrans.iastate.edu/app/uploads/2018/03/negative_moment_reinforcing_w_cvr.pdf**.