Economic Impact of Multi-Span, Prestressed Concrete Girder Bridges Designed as Simple Span versus Continuous Span

tech transfer summary

This study evaluated the cost-benefit relationship of designing multi-span, jointless bridges as simple spans versus as continuous spans for all loads.

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RESEARCH PROJECT TITLE

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PRINCIPAL INVESTIGATOR

Travis Hosteng, Bridge Research Engineer
Bridge Engineering Center
Iowa State University
515-294-7197 / kickhos@iastate.edu

CO-PRINCIPAL INVESTIGATOR

Brent Phares, Director
Bridge Engineering Center
Iowa State University

MORE INFORMATION

www.intrans.iastate.edu/

MTC
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

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Objective

The objective of this study was to determine the economic impact of designing pre-tensioned prestressed concrete beam (PPCB) bridges utilizing the continuity developed in the bridge deck as opposed to the current Iowa Department of Transportation (DOT) method of utilizing standardized spans treated as simply supported.

Background and Problem Statement

The current Iowa DOT design method for PPCB bridges utilizes a set of standard span designs, which can be combined to produce single or multi-span bridges. In the development of these standards, the spans are assumed to behave as simple spans for all applied loads. This eliminates any variation in loading and detailing requirements based on adjacent spans lengths.

In addition, the current Iowa DOT preference is for jointless design of bridges. As such, additional reinforcing steel is required in the negative moment regions (i.e., over the bridge piers) to prevent cracking and resist the additional moment. The addition of this reinforcement creates a load transfer mechanism between adjacent spans that results in continuity between adjacent bridge spans.

Iowa DOT Office of Bridges and Structures Bridge Maintenance and Inspection Unit

Five-span pre-tensioned prestressed concrete beam bridge on US 34 westbound over Danville Road and Long Creek in southeast Iowa

Other state DOTs utilize PPCB bridge design methods that assume multi-span jointless bridges behave in a continuous fashion, accounting for the continuity developed by the continuous deck and additional reinforcing. Doing so may allow for a more efficient design by accounting for the additional strength provided by continuity and the deck.

However, accounting for the continuity of the deck during design creates a more complex interaction between spans, leading to varying loading on spans. Adopting similar design methods would potentially reduce the effectiveness of using the standardized simple span designs that the Iowa DOT uses and potentially result in longer design times and higher design costs. While other standards utilize smaller precast beams, which may save on material costs, fabrication costs would most likely increase.

Research Description

This work consisted of a literature search and review, survey of other highway agencies, design comparisons, and cost-benefit analysis.

The literature review consisted of a thorough review of currently published research on related topics, including other reports on cost analysis and material optimization for the design of prestressed concrete bridges and published information on current design procedures for prestressed concrete bridges throughout the US.

The design review consisted of comparisons of the standard design practices in terms of material use and cost from a review of electronically published design manuals, standards, and practices for state DOTs. Furthermore, the design review examined design cost, as determined by design hours spent to produce final bridge plans using the different design methodologies from state DOT survey respondents.

The cost-benefit analysis was based on construction costs from the Federal Highway Administration (FHWA) National Bridge Inventory (NBI) (with corrections to account for the different years the costs were recorded and the different regional bridge locations) and material and design costs from the design review.

Key Findings

The cost-benefit comparison points fairly conclusively to simple span designs having lower initial cost than continuous bridge design methods. This conclusion is based on savings in both construction and design costs.

However, some evidence was also found for continuous designs having a lower cost. Based on the variations in the data, several continuous design bridges fell significantly below the average simple span bridge in terms of construction cost. Even with relatively high design costs, if a reasonable savings per square foot of deck area can be achieved, the design costs are easily offset for larger bridges. For example, at a reasonable $10/ft2 savings, a $24,000 design cost differential is offset for a 100 ft long bridge with a 24 ft roadway width.

Implementation Readiness and Benefits

Based on the evidence included in the final report for this project, the researchers concluded that simple span designs have a lower initial cost compared to continuous designs, in terms of construction cost and design time.

The lower construction cost demonstrated by the simple span designs in contradiction to theoretical material efficiencies in continuous design is an indicator that many of the continuous designs utilized are not optimized to the extent possible. While significant recent research has been completed on optimization methods for prestressed concrete bridge design, the majority of them remain undeveloped for practical application.

Due to the lack of strong evidence in favor of either design method in terms of long-term cost and performance, the research team concluded that simple span designs are preferable at this time.

Conclusions and Recommendations for Future Research

It is suggested that, with the maturity of design optimization methods, this study be updated to account for the potential material and time savings suggested by these optimization methods.

This study also did not look into the long-term costs associated with the design methods. Subjects of relevance for which additional research would be needed include the effects of design for continuity on deck cracking in negative moment regions, as well as long-term benefits of the reserve capacity and redundancy available in simple span jointless designs due to the unutilized continuity over the piers.