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Evaluation of the Need for Longitudinal Median Joints in Bridge Decks on Dual Structures

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Abstract
The primary objective of this project was to determine the effect of bridge width on deck cracking in bridges. Other parameters, such as bridge skew, girder spacing and type, abutment type, pier type, and number of bridge spans, were also studied. To achieve the above objectives, one bridge was selected for live-load and long-term testing. The data obtained from both field tests were used to calibrate a three-dimensional (3D) finite element model (FEM). Three different types of loading—live loading, thermal loading, and shrinkage loading—were applied. The predicted crack pattern from the FEM was compared to the crack pattern from bridge inspection results. A parametric study was conducted using the calibrated FEM. The general conclusions/recommendations are as follows: -- Longitudinal and diagonal cracking in the deck near the abutment on an integral abutment bridge is due to the temperature differences between the abutment and the deck. Although not likely to induce cracking, shrinkage of the deck concrete may further exacerbate cracks developed from thermal effects. -- Based upon a limited review of bridges in the Iowa DOT inventory, it appears that, regardless of bridge width, longitudinal and diagonal cracks are prevalent in integral abutment bridges but not in bridges with stub abutments. -- The parametric study results show that bridge width and skew have minimal effect on the strain in the deck bridge resulting from restrained thermal expansion. -- Pier type, girder type, girder spacing, and number of spans also appear to have no influence on the level of restrained thermal expansion strain in the deck near the abutment.

Keywords
Bridge decks, Bridge design, Field tests, Finite element method, Highway bridges, Jointless bridges, Literature reviews, Longitudinal cracking, Longitudinal joints, Width, continuous deck, deck cracks, diagonal cracks, thermal loading

Disciplines
Civil Engineering

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tech transfer summary

This research was designed to determine the effect of continuous bridge deck width on deck cracking.

Background and Problem Statement

For wide bridges, the Iowa Department of Transportation (DOT) requires the use of longitudinal joints, in part, to minimize deck cracking. Cracking can be induced by transverse contractions due to temperature change, shrinkage, and/or live loads. Longitudinal deck joints are thought to provide a relief point and reduce the amount of shrinkage that must be accommodated.

However, longitudinal joints have been known to allow chloride-contaminated water to penetrate the bridge deck; minimizing longitudinal joints may significantly lessen this problem. Moreover, there is little agreement among state DOTs regarding the maximum width for a continuous deck, which can range from 60 to 120 ft.

Objectives

The primary objective of this project was to determine the effect of bridge width on bridge deck cracking. Other factors, such as bridge skew, girder spacing and type, abutment type, pier type, and number of bridge spans, were also studied.

Diagonal cracks at the corner of the deck of Bridge #605220

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RESEARCH PROJECT TITLE
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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 Description

Analytical techniques including finite element analysis (FEA) were used to investigate the behavior of decks with various widths under typical loadings. Experimental field testing was also conducted, principally to help validate the analytical models.

One bridge was selected for both live-load and long-term testing, Bridge #605220 near Waterloo, Iowa. The data obtained from the field tests were used to calibrate a three-dimensional (3D) finite element model (FEM). Three different types of loading—live loading, thermal loading, and shrinkage loading—were applied to the model. The predicted crack pattern from the FEM was compared to the crack pattern from the bridge inspection results.

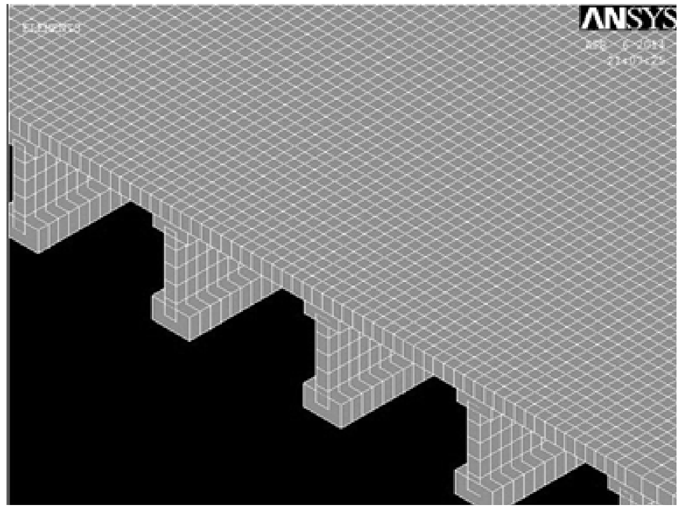
The validated model was then extrapolated in a parametric study to various other configurations—e.g., bridge skew, girder spacing and type, abutment type, pier type, and number of bridge spans—to study the influence of those parameters on cracking.

Additionally, to model potential solutions for reducing strain in the bridge deck, three solutions were preliminarily evaluated using the calibrated FEM:

1. Placing a temperature isolation pad between the soil and back side of the abutment to prevent heat transfer from the soil to the abutment
2. Adding an expansion joint within the abutment to reduce the strain in the deck
3. Increasing the amount of reinforcement steel in the deck

Key Findings

- Longitudinal and diagonal cracking in the deck of an integral abutment bridge is due to the restraint of the abutment and the temperature differences between the abutment and the deck. Shrinkage of the deck concrete, although not likely to induce cracking, may further exacerbate cracks developed from thermal effects.
- Based on the FEM study and a limited review of bridges in the Iowa DOT inventory, it appears that, regardless of bridge width, longitudinal and diagonal cracks are prevalent in integral abutment bridges but not as prevalent in bridges with stub abutments.
- The FEM parametric study results show that bridge width and skew have minimal effect on the strain in the bridge deck resulting from restrained thermal expansion.
- Pier type, girder type, girder spacing, and number of spans appear to have no influence on the level of restrained thermal expansion strain in the deck near the abutment.
- Based on the literature review results and this research, adding more transverse reinforcement steel in the deck near the abutment will not likely be effective in reducing the strain in the deck.



Mesh geometry of the bridge deck modeled by the FEM

Recommendations and Future Research

Although more research is required before some of these solutions can be put into practice, the following may reduce deck cracking:

- If deck cracking is a major concern, the use of a stub abutment is recommended.
- To obtain a better understanding of bridge deck behavior, a bridge with both integral and stub abutments is recommended to be monitored for long-term behavior and performance.
- Based on the FEM results, an effective solution to reduce deck cracking may be to place a temperature isolation pad between the soil and back side of the abutment.
- While vertical expansion joints in the abutment theoretically help reduce strain and control the maximum strain location, implementation presents several problems.

Implementation Readiness and Benefits

More research is required before putting some of the recommendations into practice. The temperature isolation pad was effective in the FEM study, but the device is conceptual at this point. While vertical expansion joints were shown to reduce strain in the FEM study, implementing these joints in an actual bridge will require further research.