Wisconsin Highway Research Program
Project 0092-16-05
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Research Brief

# Design and Performance of Highly Skewed Deck Girder Bridges

## Research Objectives

- Identify the effects of large skew on bridge analysis, design and service performance
- Develop design strategies to analyze bridges with skew and control performance issues

## Research Benefits

- Improved WisDOT's understanding of the behaviors and challenges of skewed bridge decks
- Provided design recommendations to improve performance of skewed bridges and improve deck lifespan

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## Background

Bridge skew is the angle between a line perpendicular to a superstructure and its supports. Highly skewed bridges are more complex and pose more challenges than bridges that pass perpendicularly over the road or other features below it. Skew alters distribution of loads from deck to girders. It can cause large deformations at girder ends or create stresses in the superstructure. However, as infrastructure demands increase and the amount of undeveloped land decreases, skew is becoming more commonplace in bridge construction. Thirty percent of Wisconsin bridges built between 1995 and 2014 are skewed between 20° and 60°. The goal of this project was to investigate the performance of high-skew bridges in Wisconsin to identify limits for simplified analysis methods, and to evaluate and recommend design details and practices that can mitigate negative impacts of skew on decks and bearings.

I-94's B-40-870 bridge, skewed 64° over Hank Aaron State Trail, was load tested and monitored for one year.

## Methodology

The research team reviewed inspection reports of Wisconsin bridges, interviewed maintenance engineers and inspected four bridges with skew ranging from 0° to 52° to document visible performance factors. The team performed load testing on a steel girder bridge skewed 47° and load testing with one-year monitoring on a prestressed concrete girder bridge skewed 64° to collect data on live-load and long-term response.

Two-dimensional analyses, validated with test data, were compared to American Association of State Highway Transportation (AASHTO) Load and Resistance Factor Design (LRFD) girder-line analyses on a selection of Wisconsin bridges with varying skew angles, secondary elements, bridge geometry and deck-concrete composite action. Finite element analysis was also used to study long-term displacements and stresses created by restraint against deformations.

*“Appropriate usage of the mixed bearing design will help improve the durability of our highly skewed structures throughout the state.”*

*– Philip Meinel, WisDOT*

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**Final report is available at: [WisDOT Research website](WisDOT Research website).**

## Results

Finite element models revealed that maximum shear in girders increases and moment decreases as skew increases. Two-dimensional modeling is accurate enough to study moment and shear distribution of prestressed concrete bridges and steel bridges. AASHTO specifications with WisDOT exceptions can predict load distribution, but with a small safety margin in some cases.

The skew angle of a bridge correlated positively with deck cracking. Shrinkage was the main cause of typical diagonal cracking on high skew bridge decks; temperature changes alone did not create deck cracking. High skew also caused larger superstructure in-plane displacements compared to bridges with no skew, particularly in the transverse direction. Field monitoring and modeling showed that using mixed bearing arrangements over the same pier is an efficient method to limit superstructure in-plane rotation or racking. For the bridge with mixed bearings monitored over one year, the transverse displacements remained small; longitudinal displacements were larger and correlated highly with temperature changes.

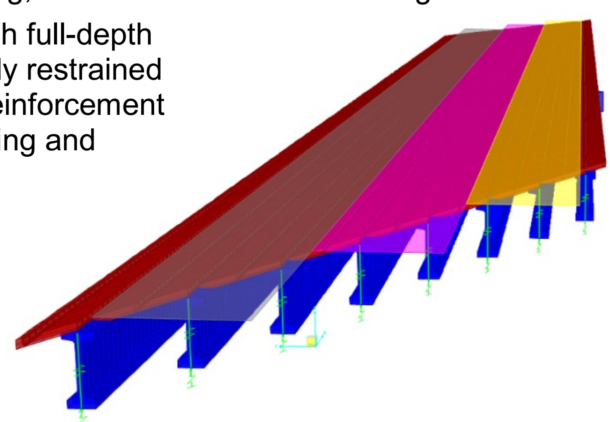
Models revealed that bridge end details affect deck cracking behavior. Reducing deck restraint limited cracking, and full-depth concrete end diaphragms and laterally restrained abutment bearings created the highest deck strains. Increasing deck reinforcement or orienting it along the skew did not reduce deck strains.

## Recommendations for Implementation

The research team offered several recommendations for the design and analysis of skewed bridges. Two-dimensional bridge analysis’ accuracy and computational efficiency should complement girder line analyses to increase safety margins in designing high-skew bridges. These analyses can also be used to estimate expansion joint displacements and fixed bearing forces.

Superstructures and bearings should be designed to accommodate for racking and expansion joint displacements. Shrinkage-controlled concrete mixtures and construction practices should be employed to reduce cracking. Mixed bearings can reduce in-plane displacements and control deck cracking, and is recommended for large skews.

Restraint of deck through full-depth end diaphragms, laterally restrained bearings or additional reinforcement may worsen deck cracking and should be avoided.



This brief summarizes Project 0092-16-05,
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