Evaluation of the Use of IRI Data to Estimate Bridge Dynamic Impact Factor (DIF)

tech transfer summary

This project correlated IRI data to impact factors and developed a process for determining the dynamic impact factor to use in permitting analysis for state-owned bridges in Iowa.

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RESEARCH PROJECT TITLE
Evaluation of the Use of IRI Data to Estimate Bridge Impact Factor

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PRINCIPAL INVESTIGATOR
Brent Phares, Bridge Research Engineer
Bridge Engineering Center
Iowa State University
bphares@iastate.edu / 515-294-5879
(orcid.org/0000-0001-5894-4774)

PRIMARY RESEARCHER
Zhengyu Liu, Research Engineer
Bridge Engineering Center
Iowa State University
(orcid.org/0000-0002-7407-0912)

MORE INFORMATION
intrans.iastate.edu

Bridge Engineering Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103
www.bec.iastate.edu

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 Impetus and Objectives

The impetus for this project was to provide information and guidance for eventual use by the Iowa Department of Transportation (DOT) on the allowable speeds for permit vehicles and other heavy loads on bridges.

The objectives of this project were to correlate international roughness index (IRI) data (which are widely collected and directly related to bridge deck roughness) to impact factors and develop a process for determining the impact factor to use for all bridges on the state highway system in Iowa in evaluating a bridge's capacity to carry a given vehicle.

Problem Statement and Project Goal

Based on the findings of a previous project, the research team concluded that bridges of "normal" roughness likely had dynamic impact factors (DIFs) less than codified values. Therefore, the result of using code values may be overly restrictive when considering the issuance of permits.

As a result, the researchers recommended that the Iowa DOT consider ways to indirectly determine the impact factor and that the road roughness information (IRI data) might be used as an indicator of the bridge entrance condition and, therefore, the impact factor.

Truck event measuring bridge dynamic response subject to a live load on one of the bridges instrumented with strain gauges

Previous Project Background

A previous project determined that the roughness at the entrance to bridges is a primary influence on general bridge DIFs (Deng and Phares 2016). With that project, a field test program was conducted on five bridges (two steel girder bridges, two prestressed concrete girder bridges, and one concrete slab bridge) to investigate the dynamic response of bridges due to vehicle loadings.

The important factors considered during the field tests included vehicle speed, entrance conditions, vehicle characteristics (i.e., empty dump truck, full dump truck, and semi-truck), and bridge geometric characteristics (i.e., long span and short span).

Three bridge deck entrance conditions were also considered—As-is, Level 1, and Level 2—which simulated different levels of roughness near the bridge deck approach. The field data were then analyzed to derive the DIFs for all gauges installed on each bridge under the different loading scenarios.

Research Description

While a comprehensive literature review was conducted for the previous project, a refined review was performed for this project to elaborate on the terms, concepts, and previous research outcomes that are related to the research topic.

To achieve the project objectives, a sample of 40 bridges having a variety of bridge lengths, skew angles, girder materials, deck conditions, structure types, etc., were identified and verified to be representative of the Iowa bridge population. A smaller sample of 20 bridges was then selected for bridge monitoring to collect dynamic strain data.

To measure the bridge dynamic response subject to live loads, the representative sample of 20 bridges was instrumented with strain gauges. Each bridge was monitored for a minimum of 10 minutes to collect data for a number of different truck types. Videos of the field testing were captured to identify the times, lanes (to match with IRI data extraction), and types of trucks passing over the bridge.

Given that the intent of the project was to provide guidance on the DIF for heavy vehicles, truck traffic was the primary interest of this study. When the data were analyzed, trucks were categorized into five possible categories: 3-axle trucks, fully/partially loaded 5-axle tractor/trailers, empty 5-axle tractor/trailers, 6-axle or more tractor/trailers, and other trucks.

The dynamic field-measured strain data from ambient traffic were then smoothed using the locally weighted scatterplot smoothing (LOWESS) function to estimate the static strain response. The maximum measured dynamic strain and estimated static strain were used to calculate the DIF for each truck event and each bridge.

IRI data were extracted from PathWeb, a web-based application provided by the Iowa DOT, for all bridges considered in the field test program. Once the bridge was identified in PathWeb, the IRI data from four locations near the bridge deck approach were extracted and used to study the relationship between the IRI and the DIF.

Key Findings

- The DIF decreases as bridge skew angle increases. Based on linear regression, the DIF value decreases about 0.037 to 0.043 per 10-degree increment of bridge skew.
- The DIF decreases as the bridge deck condition index increases, meaning that the dynamic response is lower when the bridge deck condition is better.
- For bridges with zero skew, the DIF value increases by 0.006 per 100 in/mile increment of the bridge's IRI value.

Implementation Readiness and Benefits

In some instances, permit vehicles are limited due to anticipated dynamic bridge response exceeding allowable stress levels. As such, it could be advantageous to have bridge-specific dynamic behavior estimates such that permits can be safely issued.

Given that bridge deck entrance condition had a substantial impact on the DIF in the previous work, readily available IRI data were used as a tool with this project to assign DIFs without the need for time- and resource-intensive testing of all bridges. The result is that the IRI data can be used to estimate DIF values in permitting analysis.

Given the research findings, the researchers developed an equation for the prediction of the DIF on existing bridges with consideration of the bridge skew and the maximum IRI value near the bridge deck approach. Although the equation was validated using the data from 13 bridges, the researchers recommend using the equation with the limitation that the actual bridge dynamic response could deviate ±10% from the equation predicted value.

Reference

Deng, Y. and B. Phares. 2016. *Investigation of the Effect of Speed on the Dynamic Impact Factor for Bridges with Different Entrance Conditions*. Bridge Engineering Center, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/2018/03/dynamic_impact_factor_for_bridge_entrances_w_cvr.pdf.