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RESEARCH PROJECT TITLE

Investigation of the Effect of Speed on the Dynamic Impact Factor for Bridges with Different Entrance Conditions

SPONSORS

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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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tech transfer summary

The results of this work provide information on the allowable speeds for trucks, and permitted vehicles and loads in particular, on bridges.

Background and Problem Statement

The dynamic interaction of vehicles and bridges results in live loads being induced into bridges that are greater than the vehicle's static weight. Consideration of this phenomena has been included in the American Association of State Highway Transportation Official (AASHTO) Bridge Design Specifications for many years. While the specifications have been modified over the years, questions remain about how much of an effect dynamic interaction plays.

In recognition of this interaction, the Iowa Department of Transportation (DOT) currently requires that, in some instances, permitted trucks slow to five miles per hour and span the roadway centerline when crossing a bridge. Such a slowing is consistent with current specifications, which indicate that a lower dynamic impact factor may then be used for permitted vehicles. The positive effect of this is that larger loads may be allowed to cross Iowa's bridges.

However, this practice has other negative consequences. For example, the reduction in speed increases the potential for crashes, uses additional fuel, and, in some cases, may be downright impractical for bridges with high traffic volumes. In addition, the reduction in speed can have an impact on the orderly flow of traffic.



One of the five bridges, the short-span steel girder bridge, that the researchers instrumented and used for load testing

Objective and Scope

The primary objective of this work was to provide information and guidance on the allowable speeds for trucks, and permitted vehicles and loads in particular, on bridges. The research needed to take into account the many factors that affect the dynamic response of a bridge under vehicular traffic including vehicle speed, vehicle characteristics, bridge dynamic characteristics, and roughness of the bridge approach.

Research Description and Methodology

After a brief literature search and review to investigate other related work, a field test program was implemented on five bridges (two steel girder, two pre-stressed concrete girder, and one slab) to investigate the dynamic response of bridges due to vehicle loadings. The researchers installed strain gauges and then collected data as a series of trucks crossed over each bridge.

The important factors taken into account during the field tests included vehicle speed, entrance conditions, vehicle characteristics (empty dump truck, full dump truck, or semi-truck), and bridge geometric characteristics (long-span or short-span). These were the three entrance conditions that the researchers used: As-is and Level 1 and Level 2, which simulated rough entrance conditions with a fabricated ramp placed 10 feet from the joint between the bridge end and approach slab and directly next to the joint, respectively.

15 load cases for each type of truck

As-is	Empty dump Full dump Semi	Crawl	LC1
		10 mph	LC2
		20 mph	LC3
		30 mph	LC4
		50 mph	LC5
Level 1	Empty dump Full dump Semi	Crawl	LC6
		10 mph	LC7
		20 mph	LC8
		30 mph	LC9
		50 mph	LC10
Level 2	Empty dump Full dump Semi	Crawl	LC11
		10 mph	LC12
		20 mph	LC13
		30 mph	LC14
		50 mph	LC15

Simulated rough entrance conditions:

Level 1 = Timber ramp 10 ft away from the joint

Level 2 = Timber ramp directly next to the joint

The researchers analyzed and utilized the field data to derive the dynamic impact factors (DIFs) for all strain gauges installed on each bridge under the different loading scenarios. They calculated DIFs by comparing the high-speed results to those obtained from testing at low (crawl) speeds.



Strain gauges installed on concrete slab bridge



Empty dump truck crossing the instrumented slab bridge with As-is entrance conditions during load testing



Empty dump truck crossing the instrumented slab bridge with Level 1 entrance conditions (fabricated ramp 10 ft from joint)



Semi-truck crossing the instrumented slab bridge with Level 2 entrance conditions (fabricated ramp at the approach joint)

Key Findings

- The DIFs increase as the static strain decreases and the DIFs are sensitive to low strains, and particularly those less than 10 microstrains, which is likely due to the measurement error, noise, and mathematical division. Given the project objectives were related to permitted trucks, DIFs from higher strain readings were utilized for the final part of the study.
- The DIF increased with an increase of the truck speed, particularly for the 30 and 50 mph travel speeds that were field tested.
- The empty dump truck induced the greatest impact factors, followed by the full dump truck and then the semi-truck.
- Longer span bridges had lower DIFs than shorter span bridges, likely due to the higher flexibility of longer span bridges.
- Greater entrance condition roughness generally resulted in higher DIFs. However, the roughest entrance condition (Level 2, with the ramp placed at the joint) did not always induce the largest DIFs. With Level 1 and Level 2 entrance conditions, the DIFs exceeded 0.3 for all investigated bridges for truck speeds up to 50 mph. With As-is entrance conditions, the DIFs were less than 0.3 for the steel and concrete girder bridges and less than 0.1 for the slab bridge with truck speeds up to 50 mph.

To complement the Iowa DOT policy, the researchers determined allowable speeds for each of the bridges tested where the DIFs did not exceed 0.1 as follows:

- For the long steel girder bridge, the allowable truck speeds were 30, 10, and 10 mph for As-is, Level 1, and Level 2 entrance conditions, respectively. For the short steel girder bridge, the allowable truck speeds were 30 mph, crawl speed, and crawl speed for As-is, Level 1, and Level 2 entrance conditions, respectively.

- For the long concrete girder bridge, the allowable truck speeds were 30, 30, and 20 mph for As-is, Level 1, and Level 2 entrance conditions, respectively. For the short concrete girder bridge, the allowable truck speeds were 50 mph, 10mph, and crawl speed for As-is, Level 1, and Level 2 entrance conditions, respectively.
- For the slab bridge, the allowable truck speeds were 50 mph, crawl speed, and crawl speed for As-is, Level 1, and Level 2 entrance conditions, respectively.

Implementation Readiness and Benefits

The results of this investigation will help Iowa DOT staff evaluate current policy and perhaps develop updated guidelines to refine practices related to bridge-vehicle interaction.

In order to limit the DIF to no more than 0.1, for all bridge types with entrance conditions similar to those tested, the allowable truck speeds for permitted vehicles and loads are 30 mph for As-is and crawl for Level 1 and Level 2.

The researchers recommend that currently collected road roughness information be examined for use as an indicator of entrance condition. If successful, the international roughness index (IRI) data could then be used to determine the speed limitation to put in place as well as which DIF values to use in permitting analysis.

Future Research

From this study, the researchers found that heavier trucks induce greater strains in bridges on which the measurement error, noise, and mathematical division have less impact. In the future, additional field tests can be conducted using heavier trucks (i.e., the truck weight close to the AASHTO design truck) to obtain more realistic DIFs for design or rating purposes.

Furthermore, the long-term bridge monitoring systems installed on Interstate 80 should be used to study impact factors and stress levels for actual permitted vehicles. Utilizing these data will provide the best information as to what level permitted vehicles traveling at highway speeds induce dynamic effects in bridges.