Investigation of the Impact of Dual-Lane Axle Spacing on Lateral Load Distribution

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RESEARCH PROJECT TITLE
Investigation of the Impact of Dual-Lane Axle Spacing on Lateral Load Distribution

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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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Axle weight limits per lane for different types of dual-lane loads were determined and recommended to complement current policy and specifications through this study.

Background

With ever-increasing numbers and the sizes of permitted vehicles and loads crossing Iowa's highways and bridges, it has become more and more common for oversized, overweight vehicles to travel on at least four wheel lines that are evenly or unevenly spaced. The spacing of the adjacent wheel lines of dual-lane loads induces different lateral live load distributions on bridges, which cannot be determined using the current American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) or Load Factor Design (LFD) equations, which are only applicable for vehicles with standard axle configurations.

Problem Statement

Current Iowa law requires dual-lane loads to meet a five-foot requirement (i.e., interior wheel-line spacing no less than five feet) or the maximum weight of each axle cannot exceed 20,000 pounds (20 kips). It is necessary to understand the actual effects of wheel-line spacing on lateral load distribution, such that the five-foot requirement of the Iowa Department of Transportation (DOT) policy can be justified or improved and the applicability of the AASHTO LRFD or LFD equations to dual-lane loads can be determined.

Objective

The main objective of this research was to investigate the impact of the wheel-line spacing of dual-lane loads on the lateral load distribution on bridges.

Research Description and Methodology

After a brief literature search and review to investigate other related work, a numerical evaluation using finite element (FE) models was performed to investigate the lateral load distribution of dual-lane loads on three types of common Iowa bridges: steel girder, pre-stressed concrete girder, and slab.

A database containing 1,721 prestressed-concrete bridges, 979 steel bridges, and 556 slab bridges was provided by the Iowa DOT staff. A sub-database consisting of the bridges with skew angles less than 10 degrees and no more than three spans was further extracted from the database. For simulation purposes, 20 bridges of each type (60, total) were randomly sampled from the sub-database and used in the evaluation program.

Two-dimensional linear elastic FE models of the selected bridges were established to derive the load distribution factors (LDFs) for the concrete and steel bridges and the equivalent lengths of the slab bridges. To study the variations of LDFs with respect to wheel-line spacing, 22 types of single-axle four-wheel-line dual-lane loads were taken into account with load configurations consisting of combinations of various interior and exterior wheel-line spacing.

Based on the FE results, a similar procedure was used to derive the moment LDFs for the 20 steel bridges and 20 concrete bridges, the shear LDFs for the 20 steel bridges, and the equivalent widths of the 20 slab bridges. The moment and shear LDFs were determined based on the internal forces in girders at critical cross-sections. The equivalent widths of the slab bridges were calculated based on the strain distributions in the deck at critical bridge cross-sections. For comparison purposes, the corresponding moment and shear LDFs and equivalent widths were also derived using the AASHTO equations.

The adequacy of the Iowa DOT five-foot requirement was evaluated by comparing the LDFs and equivalent widths obtained using the FE models to those obtained using the AASHTO equations. The axle weight limits per lane for different dual-lane load types were determined based on a baseline axle weight limit of 20 kips times the final LDF or equivalent length ratio. The final recommended axle weight limit for each dual-lane load type was also determined through selection of the lowest values for all of the investigated bridge types.

Key Findings

- The moment LDFs in the negative moment regions were almost the same as those in the positive moment regions for both exterior and interior girders of the steel and concrete girder bridges.

- The AASHTO LRFD and LFD equations sometimes overestimated and sometimes underestimated moment LDFs based on the FE results. For the interior girders of the concrete girder bridges, the LRFD equations provided good estimations of the moment LDFs and the LFD equations underestimated the moment LDFs. For the exterior girders of the concrete girder bridges, both the LRFD equations and the LFD equations overestimated the moment LDFs. For the interior girders of the steel girder bridges, the LRFD equations underestimated the moment LDFs and the LFD equations overestimated the moment LDFs. For the exterior girders of the steel girder bridges, the LRFD equations underestimated the moment LDFs of the exterior girders and the LFD equations overestimated the moment LDFs.

- The AASHTO LRFD and LFD equations also either overestimated or underestimated shear LDFs based on the FE results. For interior girders of the steel girder bridges, both the LRFD equations and the LFD equations underestimated the shear LDFs. For the exterior girders of the steel bridges, both the LRFD and LFD equations overestimated the shear LDFs.

- The LRFD equations slightly overestimated the equivalent widths in the positive moment regions and slightly underestimated the equivalent widths in the negative moment regions.

- The LRFD equations gave more consistent predictions than the LFD equations. For the most part, no significant relationships were found between the important bridge parameters and the accuracy of AASHTO equations in the prediction of LDFs and equivalent widths, although some general trends were found. For instance, the LRFD equations were less conservative for both moment and shear LDFs when the number of girders was no more than five, and the equivalent widths predicted using LRFD equations were less conservative when the modified span length was longer than 30 ft.

Conclusions and Recommendations

- The Iowa DOT current practice on the moment and shear LDFs and equivalent widths for dual-lane loads is reasonable and adequate.

- The research team found that a lighter axle weight limit should be used for dual-lane loads with narrower wheel-line spacing.

Implementation Readiness and Benefits

Based on the derived LDFs and equivalent lengths, the axle weight limits per lane for different types of dual-lane loads were determined and could be used to complement the current Iowa DOT policy and AASHTO code specifications.

Future Research

The results from the FE simulations in this study indicate that the LDFs for the investigated four-girder steel and concrete bridges are underestimated using the AASHTO LRFD equations. For improvement purposes, future work can be focused on development of more accurate equations for estimating LDFs for four-girder steel and concrete bridges.