Impact of Legalized 25-kip Axle Loads for Self-Propelled Implements of Husbandry on Iowa Bridges

tech transfer summary

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RESEARCH PROJECT TITLE
Impact of Legalized 25-kip Axle Loads for Self-Propelled Implements of Husbandry on Iowa Bridges

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PRINCIPAL INVESTIGATOR
Justin Dahlberg, Director
Bridge Engineering Center
Iowa State University
dahlberg@iastate.edu / 515-294-5664
(orcid.org/0000-0002-6184-4122)

CO-PRINCIPAL INVESTIGATOR
Brent Phares, Bridge Research Engineer
Bridge Engineering Center
Iowa State University
(orcid.org/0000-0001-5894-4774)

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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A recent increase in the allowable weight limit for terragator-type vehicles in Iowa prompted an assessment of bridge behavior under these increased loads and the applicability of codified values for bridge design and evaluation.

Objectives

This research aimed to assess bridge behavior under terragator-type implements of husbandry (IoH) with 25 kip axle loads. The key objectives were as follows:

1. Identify current in-service terragator-type legal vehicles per Iowa Code 321.463.a(1)(2).
2. Perform live load tests of bridges using terragator vehicles to determine actual live load distribution and dynamic impact factors and to calibrate bridge models.
3. Develop bridge models using finite element (FE) numerical analysis and simulate the load effects due to terragator-type vehicle crossings.
4. Compare live load distribution results to current codified live load distribution factors (LLDFs) used for typical vehicle types.
5. Compare dynamic impact factors to codified dynamic load factors.
6. Calibrate live load factors for load and resistance factor design (LRFD) and load and resistance factor rating (LRFR).
7. Develop a legally loaded terragator-type vehicle model for Iowa.

Background and Problem Statement

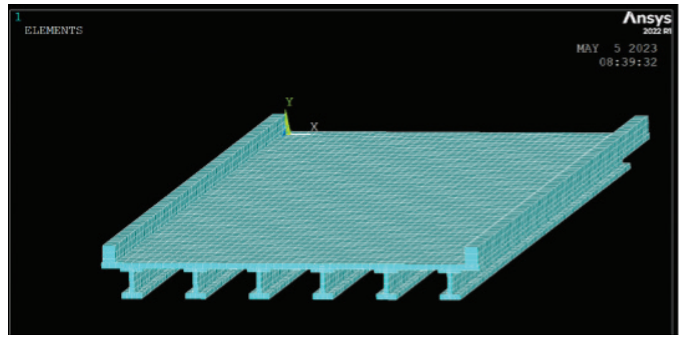
In February 2019, Iowa House Study Bill 218 amended Section 321.463 of the Iowa Code to effectively codify the allowable axle weight limit for certain implements of husbandry, commonly referred to as terragators, to 25 kips. Under the amendment, permitted axles loads on Iowa bridges are now above those calculated using the Federal Bridge Formula.

This change poses a particular concern to those who oversee and manage the design, rating, and preservation of bridge structures because the resulting structural response of bridges could exceed that which would otherwise be seen from other legal loads.

An increased allowable weight limit on single axles increases the likelihood that the maximum structural response (stress, deflection) of bridges will become greater as vehicle operators begin taking advantage of the increased load limit. Subjecting bridges to increased loads has potentially damaging effects, including premature degradation or failure.

It is important to fully understand the load response of bridges to these unique vehicles relative to more common vehicle configurations. Such an understanding will allow bridge owners to take appropriate action if/when needed and/or necessary.

Terragator-type IoH



Typical FE model of a PC bridge

Research Description

The impact of legally allowed 25-kip axle loads on bridges was assessed through field and analytical studies.

Live load tests of several bridges were conducted using the IoH vehicle type that was affected by the state legislation to observe the transverse load distribution of the bridges and the dynamic impacts of the IoH. The data were also compared to current design codes published by the American Association of State Highway and Transportation Officials (AASHTO).

FE models were developed for the field-tested bridges and validated using the field test data. Numerous FE models of other existing bridges were created for use in a parametric study that assessed the influence of various bridge parameters on the load distribution factors. A database of currently used terragator-type vehicles was developed to use for live load input data.

Instrumentation of a bridge for live load testing

Live load factors for 23 prestressed concrete (PC) bridges and 23 steel girder bridges were found using a calibration process based on reliability theory. The maximum moment and shear resulting from live loads were calculated. The dead loads of bridge components were also calculated to find the dead load factors. The moment and shear capacity of the bridge components were calculated and used as resistance data for the calibration process.

The live load factor for each bridge type was calculated using three cases. Case I calibrated the load and resistance factors (LRFs) for the identified terragators in the Strength I limit state. Cases II and III calibrated the LRFs for a hypothetical terragator model (Terragator Max) in the Strength I and II limit states, respectively. The coefficient of variation for the live load data was taken from Case I.

Live load factors were calibrated using two safety indices. A target safety index of 3.5 was chosen to reflect reliability theory and LRFD philosophy. A safety index of 2.0 was chosen to reflect the less conservative approach used for load rating.

Key Findings

A comparison of the field test data results to current AASHTO design codes yielded the following observations:

- For PC bridges, the LLDFs for interior girders subject to single-wheel axles were higher than the AASHTO LLDFs, though these axles typically are lightly loaded relative to the legal allowance and result in relatively low strain magnitudes. For exterior girders, the AASHTO LLDFs were higher than those calculated based on the field tests.
- Slab-type bridges exhibited a greater distribution of the live load than what is calculated in design. Thicker slabs reduced the load intensity on a unit strip width and distributed the load more evenly across a larger strip width.
- The calculated dynamic impact factor (DIF) was influenced by vehicle speed, with the DIF incrementally increasing as speeds increased. All but one of the experimentally determined DIF values were less than 1.33, which is the AASHTO-prescribed DIF. The single exception was for an empty terragator on a skewed bridge.

The parametric study yielded the following results:

- The load distribution factors resulting from the parametric study are captured by the AASHTO load distribution factor equations.
- The interior and exterior girder LLDFs for PC bridges and steel girder bridges were less than the LLDFs calculated from the AASHTO-prescribed equations.
- The calculated equivalent strip width for slab bridges was larger than the strip width calculated using the AASHTO-prescribed equation.
- The bridge parameters that primarily influence the interior girder LLDFs for both PC and steel girder bridges are skew angle, girder spacing, and total number of girders.
- The ratio of girder spacing to span length showed the greatest effect on the LLDFs of PC and steel girder bridges. For slab bridges, the parameters with the greatest influence on the equivalent strip width were skew angle, slab thickness, and span length.

The calibration of live load factors yielded the following key findings:

- A comparison of the Case I LRFs with the Strength I AASHTO LRFs suggests that an update to the AASHTO LRFs is not needed for existing terragator loads as long as the axle loads comply with the legal load limit of 25 kips.
- For a target safety index of 3.5, a comparison of the Case II LRFs with the Strength I AASHTO LRFs suggests that the current live load factor of 1.75 for Strength I should be increased to 1.90 if husbandry vehicles similar to Terragator Max are manufactured.
- When a target safety index of 2.0 is considered, the same case does not suggest an update to the AASHTO live load factor.
- A comparison of the Case III LRFs with the Strength II AASHTO LRFs suggests that an update to the AASHTO Strength II LRFs is not required.
- The dead load factors were found to be lower than the current AASHTO-recommended values. Therefore an update to the AASHTO LRFs is not required.
- The resistance factors were found to be close to the AASHTO resistance factors for moment and shear.
- The findings suggest that the live load factors in the current AASHTO LRFD do not require an update because an IoH with a vehicle configuration similar to that of Terragator Max is unlikely to be produced. Terragator Max was developed by considering a conservative and hypothetical vehicle configuration.

Implementation Readiness and Benefits

Understanding the load response of bridges to terragator-type vehicles with axle loads of up to 25 kips helps bridge owners make informed decisions regarding the design, rating, and preservation of bridge structures.

Though subjecting bridges to increased loads has potentially damaging effects, this research found that the AASHTO LRFs do not need to be updated to reflect Iowa's legal axle load of 25 kips.