Study of the Impacts of Implements of Husbandry on Bridges

tech transfer summary

The impacts of farming vehicles on bridges are not well understood and are not explicitly encompassed within the design, rating, and posting vehicles presented in current specifications.

Problem Statement

Little is known about how agricultural vehicles, which come in a variety of configurations and are known as implements of husbandry, affect bridges on our secondary roadways. The behavior of bridges with these vehicles, particularly in regard to live load distribution and impact, is not explicitly encompassed within the design, rating, and posting vehicles presented in current American Association of State Highway and Transportation Officials (AASHTO) specifications.

Due to the large axle loads and varying axle spacings associated with implements of husbandry, the current AASHTO vehicles used for bridge testing, such as the HL-93 design truck and the HS20 rating truck, may not accurately represent husbandry vehicles.

Project Objectives

The objectives of this study were to develop guidance for engineers on how implements of husbandry loads are resisted by traditional bridges, with a specific focus on bridges commonly found on the secondary road system; provide recommendations for accurately analyzing bridges for these loading effects; and make suggestions for the rating and posting of these bridges.

Vehicles used in field testing included a tractor towing a three-axle liquid manure applicator, also known as a honey wagon tank

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RESEARCH PROJECT TITLE
Study of the Impacts of Implements of Husbandry on Bridges

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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.

IOWA STATE UNIVERSITY
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Background

The deterioration of bridges is a prevalent issue in the US. A portion of that deterioration comes from the frequent subjection of bridges to oversized loads, including those from implements of husbandry.

Although states' definitions vary, this study's survey results (received from 22 states) showed that an implement of husbandry generally describes a vehicle used in agricultural activities. Some states do not have a legal definition at all, whereas others have criteria as specific as axle weight and tire configuration.

Field Testing and Analytical Models

The first component of the research focused on determining the impacts of husbandry vehicles on actual bridges through field testing and analytical finite element models.

This study focused on the most common bridge types used for secondary roadways in the Midwest. Field testing was conducted on 19 in-service bridges, including bridges with steel girders and either concrete or timber decks as well as bridges with timber girders and timber decks. The bridges included 5 steel-concrete bridges, 11 steel-timber bridges and 3 timber-timber bridges.

The heaviest vehicles that could safely cross the field test bridges without overloading, overstressing, or causing damage were calculated. The state rating engineer approved the final selection of the load testing vehicles, which included four farm vehicles and a five-axle semi-truck.

The farm vehicles included a tractor with a liquid manure applicator (called a honey wagon tank), a tractor with two honey wagon tanks, an agricultural fertilizer spreader (or TerraGator), and a tractor with a grain wagon.

The field test data were used to determine a reasonable bound for the impact factors of husbandry vehicles and initially understand how live load moments created by husbandry vehicles are distributed among the girders.

In addition to the load tests, finite element models were created for the 19 bridges and calibrated using the field test results. Using these 19 initial models as guidelines, finite element models were created for 151 bridges included in the inventory. These models were subjected to the loads of 121 typical husbandry vehicles.

The results of the field testing and analytical models were used to provide recommendations on upper limits for dynamic load allowances (IMs), as well as several equations for determining live load distribution factors (LLDFs) specifically for implements of husbandry.

Elevation view of one of the five steel-concrete bridges used for field testing

Ratings and Postings

The second component of the research aimed to determine whether current AASHTO rating and posting vehicles could be used to represent husbandry vehicles.

Software developed by Iowa State University's Bridge Engineering Center was used to theoretically drive AASHTO vehicles and the 121 husbandry vehicles used in the finite element models across 174 bridges. Using the moments produced by both the AASHTO and husbandry vehicles on these bridges, comparisons were made among the moment envelopes for both vehicle types and among the theoretical operating ratings for both vehicle types.

The results were used to develop an overarching husbandry vehicle, recommend signage and posting for husbandry vehicles, and generate bridge rating examples for both short- and long-span bridges using the updated distribution and impact factors from the first component of this research.

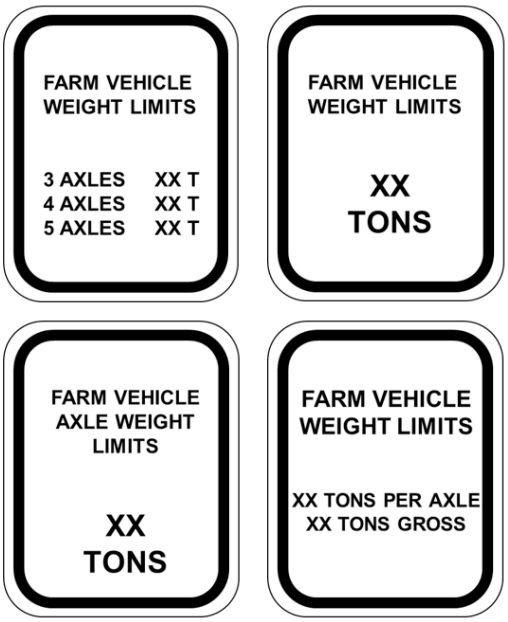
Key Findings and Conclusions

Field Testing and Analytical Models

- For the field-tested bridges and vehicles, an upper bound to the dynamic load allowance (IM) was estimated to be 60 percent.
- For the most part, the empirical equations developed from the field testing and analytical modeling provided a good estimation of LLDFs. Exceptions are single-lane steel-concrete and multilane timber-timber bridges, which had limited representation in this study.
- The LLDFs provided in current AASHTO specifications are, in some cases, different from the LLDFs for the 151 bridges and 121 husbandry vehicles in the finite element analyses.

Ratings and Postings

- The vehicles provided in the current AASHTO specifications were not found to accurately represent the effects caused by husbandry vehicles.
- On shorter span bridges (less than 40 ft), husbandry vehicles tend to produce lower operating ratings than the AASHTO vehicles, and the overarching husbandry vehicle might control rating and/or posting. On longer span bridges, husbandry vehicles seem to lead to higher operating ratings than AASHTO vehicles, and the current rating and posting vehicles would control rating and/or posting.
- Using a separate restriction sign for farm vehicles is considered to be a practical way to improve bridge safety while avoiding over-posting for other types of vehicles.



Possible farm vehicle posting signs: weight limits for three-, four-, and five-axle farm vehicles (upper left), farm vehicle gross-vehicle-weight limit (upper right), axle-weight limit for farm vehicles (lower left), and limits for gross-vehicle-weight and axle-weight for farm vehicles (lower right)

Implementation Benefits and Readiness

This research provides much-needed information about the effects of husbandry vehicles on bridges and the applicability of current AASHTO specifications for these vehicles.

The empirical equations developed from the field testing and finite element modeling provide a good estimation of the LLDFs and are recommended for consideration in designing and rating slab-over-girder bridges for husbandry vehicles. However, the equations have limitations in that small numbers of some bridge types were included in the analysis. More steel-concrete, steel-timber, and timber-timber bridges should be added to the study to increase the confidence in the empirical equations.

Suggested bridge restriction signs, including speed limit and load posting signs, were developed based on the AASHTO Manual for Bridge Evaluation and the Federal Highway Administration (FHWA) Manual on Uniform Traffic Control Devices for Streets and Highways.

It is recommended that this study be extended to other bridge types on secondary roadways and subjected to husbandry vehicle loading. Additionally, because a limited amount of dynamic data was available, further investigation of the IM of husbandry vehicles would be appropriate.

Possible farm vehicle speed limit sign