

Development of Rural Road Bridge Weigh-in-Motion System to Assess Weight and Configuration of Farm-to-Market Vehicles

Final Report
May 2018



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16. Abstract <p>The weights and configurations of large vehicles traveling the primary interstate system are known with relative certainty due to the information collected at numerous weigh stations. It is uncommon, however, that farm-to-market vehicles and other implements of husbandry (IoH) travel the interstate system; thus, an accurate assessment of the characteristics of these vehicles is left unknown. Since these vehicles commonly travel rural roads, and often at weights exceeding the legal limit especially during harvest, an accurate understanding of low-volume road usage is necessary to properly plan for the near-term repair and replacement of structures and roadways; even more, the information collected will help improve the long-term performance and asset management activities.</p> <p>A recently completed pooled-fund project, which the Iowa Department of Transportation (DOT) was the lead state on, looked to assess the impact of implements of husbandry on bridges. Those efforts produced valuable information especially as it relates to lateral load distribution. Even so, the project was largely completed using a database of virtual vehicles developed through information provided by equipment manufacturers and rule-of-thumb. Although it is believed the database generally represented current vehicles, the accuracy cannot be verified without direct measurement of all vehicles. Furthermore, one piece of missing information is the frequency with which those vehicles cross low-volume road bridges.</p> <p>The objective of this project was to develop a portable weigh-in-motion system using a rural road bridge to estimate the characteristics of vehicles traveling these roads. A unique instrumentation setup was utilized with strain gages placed on the bottom face of the deck as well as on the top and bottom flanges of the girders, which allowed for the application of algorithms for vehicle classification determination. Further classification of the IoH vehicles is made possible by actual determination of specific vehicle type based on strain response and the corresponding number and spacing of axles. This vehicle information provides actual loading and corresponding bridge response and, thus, maintenance decisions and actual structural demands can be properly selected based on existing traffic types and frequencies. The system developed for this project can be deployed on rural bridges for realistic traffic classifications.</p>			
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DEVELOPMENT OF RURAL ROAD BRIDGE WEIGH-IN-MOTION SYSTEM TO ASSESS WEIGHT AND CONFIGURATION OF FARM-TO-MARKET VEHICLES

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BACKGROUND AND OBJECTIVES

The weights and configurations of large vehicles traveling the primary interstate system are known with relative certainty due to the information collected at numerous weigh stations. It is uncommon, however, that farm-to-market vehicles and other implements of husbandry (IoH) travel the interstate system; thus, an accurate assessment of the characteristics of these vehicles is left unknown. Since these vehicles commonly travel rural roads, and often at weights exceeding the legal limit, an accurate understanding of low-volume road usage is necessary to properly plan for the near-term repair and replacement of structures and roadways.

A recently completed pooled-fund project, led by the Iowa Department of Transportation (DOT), assessed the impact of implements of husbandry on bridges. Those efforts produced valuable information, especially as it relates to lateral load distribution. Even so, the project was largely completed using a database of virtual vehicles developed through information provided by equipment manufacturers and rule-of-thumb. Though it is believed the database generally represented current vehicles, the accuracy cannot be verified without direct measurement of all vehicles. Further, one piece of missing information is the frequency with which those vehicles cross low-volume road bridges.

The objectives of this project are to determine the frequency of crossings, capture the bridge behavior under dynamic loads, and estimate the characteristics of husbandry vehicles while they are traveling over rural road bridges. From this information, decision makers will have objective qualitative information from which they can base their decisions.

RESEARCH METHODOLOGY

To acquire loading characteristics of IoH vehicles, a bridge located on Story County Road (CR) E-18 in Iowa was instrumented. This 28 ft wide, 48 ft long single-span bridge was constructed in 1967 per the Iowa DOT V13-1-64 Bridge Standard. The bridge consists of four steel girders and a concrete deck and is representative of a typical farm-to-market road bridge (see Figure 1).



Figure 1. Instrumented bridge located on Story County Road E-18

The unique instrumentation setup included 24 strain gages placed on the bridge deck bottom, and top and bottom flanges of the girders, as shown in Figure 2.

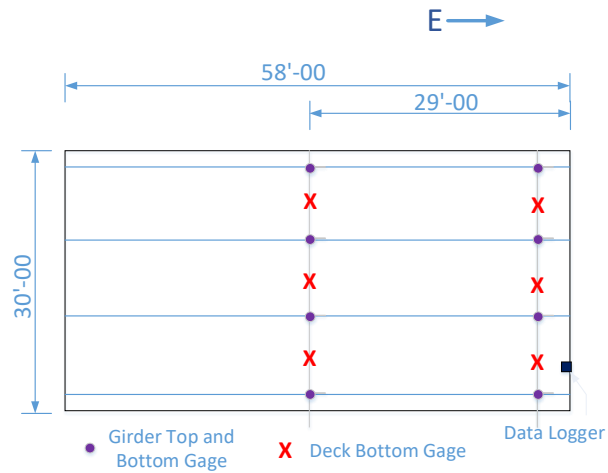


Figure 2. Placement of 24 strain gages on bridge

Data was collected from September 2014 through November 2014, with the collected strain data used for vehicle footprint recognition and maximum strain analysis. A motion-triggered camera was also installed for image capturing and vehicle validation purposes.

DATA ANALYSIS

The pictures of captured vehicles were manually classified into IoH vehicles and non-IoH vehicles, and a program was developed for strain data visualization. Of the almost 16,000 vehicles that crossed the bridge during the period of data acquisition, roughly 2% of them were IoH vehicles. The strain data file that matches the picture of an IoH vehicle was determined by two major factors: 1) the time stamps; and 2) the number of axles shown by the deck bottom strains and/or strain change rate. Based upon the maximum strain caused by a particular vehicle, categorization of the IoH vehicles could be performed. Figure 3 shows a histogram of the maximum strains at mid-span for the bottom flange of the beams.

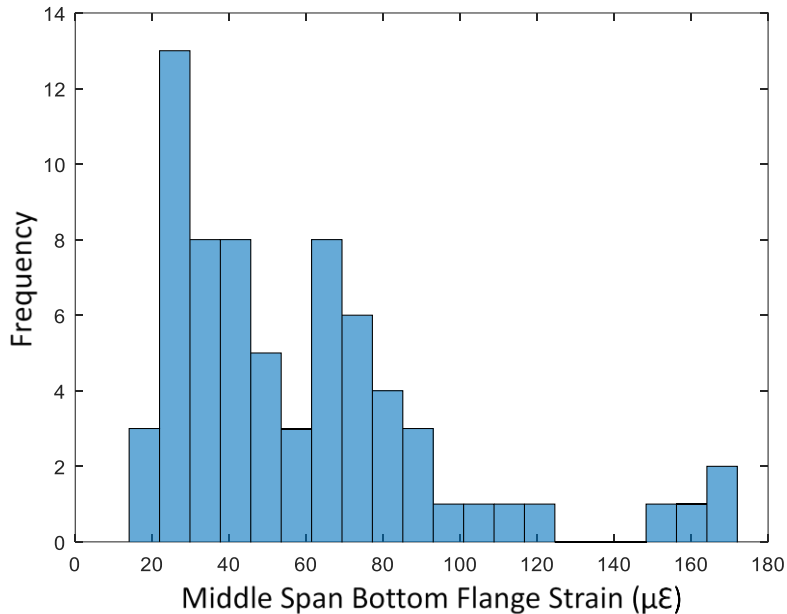


Figure 3. Maximum strain at middle span bottom flange

Two obvious groups can be identified from the distribution – a larger strain group ($> 50 \mu\epsilon$) and a smaller strain group ($< 50 \mu\epsilon$), which correspond to heavy and light IoH vehicles, respectively. Based upon the described data analysis and categorization process, among the 69 IoH vehicles with coinciding strain data available, 34 were considered heavy vehicles and 35 were light. Images of vehicles from both categories are shown in Figures 4 and 5.



Figure 4. Heavy IoH vehicles

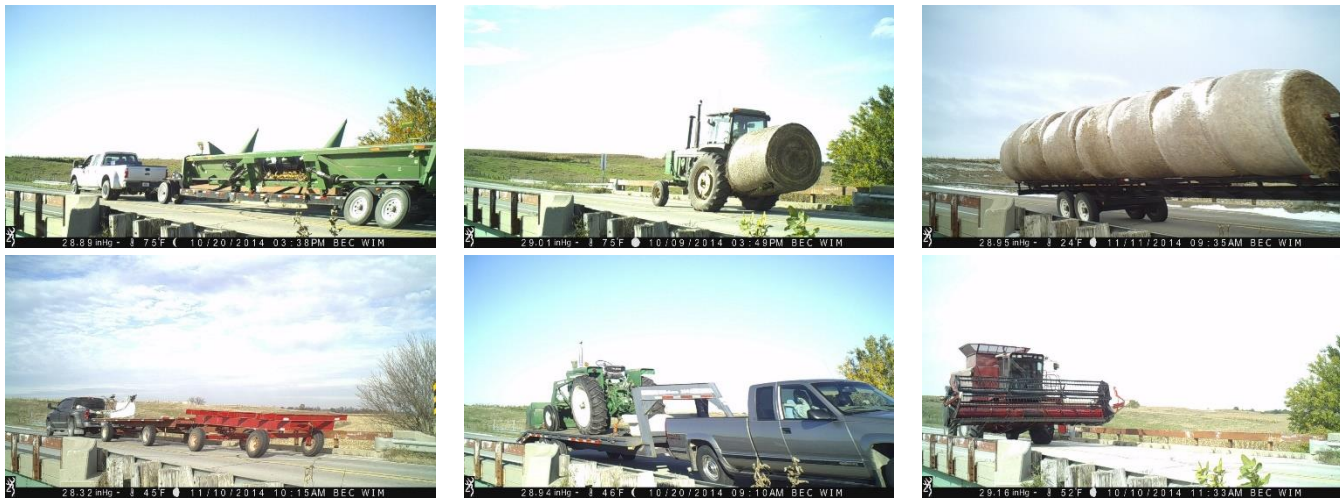


Figure 5. Light IoH vehicles

VEHICLE CHARACTERISTICS

Aside from providing heavy and light IoH vehicle categorizations, the strain data also provides valuable information for vehicle type classification. In conjunction with a database of husbandry vehicles and processing techniques obtained from a supplemental pool-fund project (see <http://www.intrans.iastate.edu/research/projects/detail/?projectID=1264789457>), bottom deck strain data and strain change rate data obtained from the bridge proved useful. For example, consider that the system captured a vehicle crossing the bridge. Based upon the level of strain induced, passenger vehicles can be filtered out, such that only heavy trucks and husbandry implements are of interest for further data analysis. As a result of this filtering, the data shown in Figure 6 is of interest for categorization.

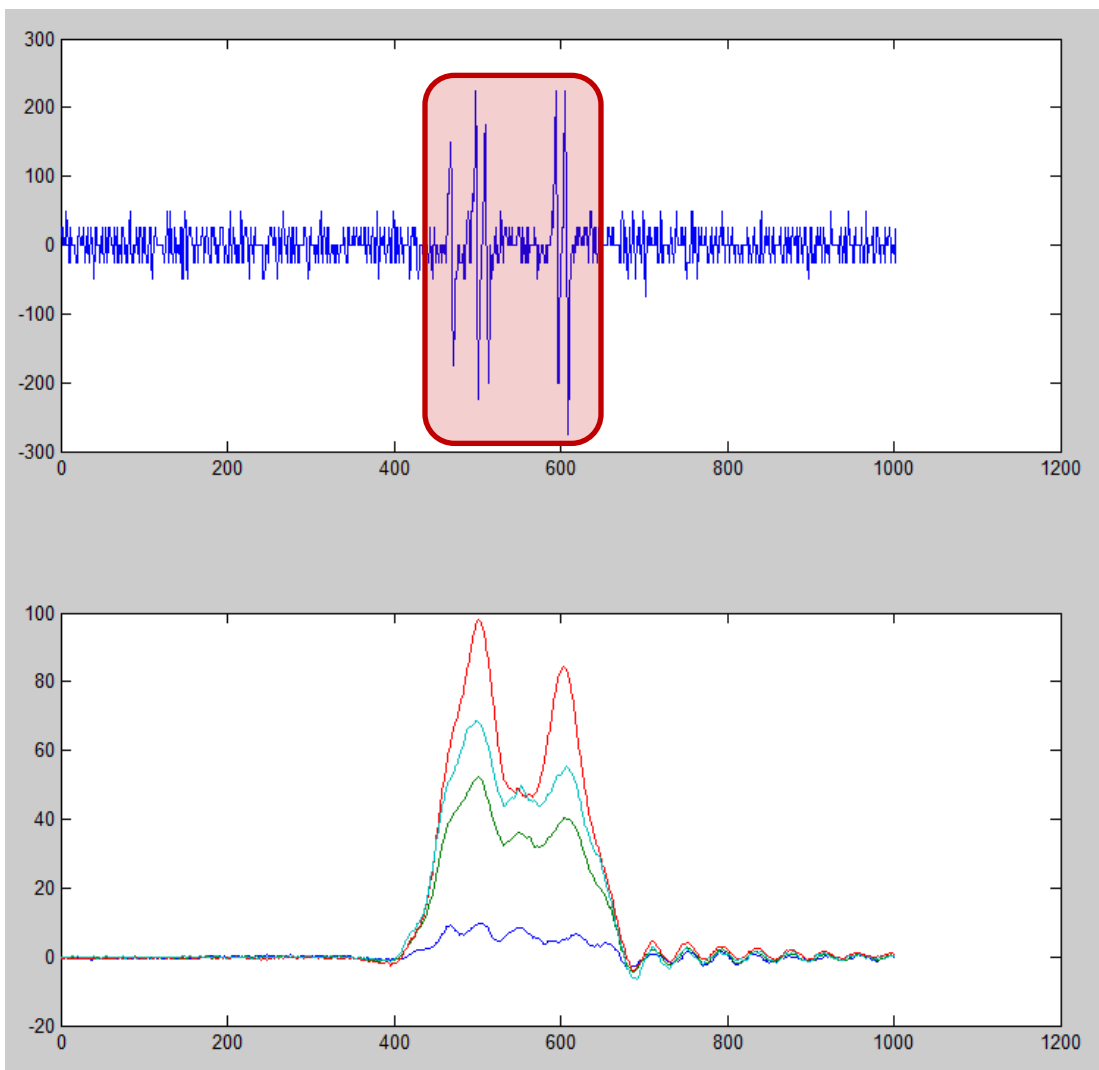


Figure 6. Sample strain and strain change rate data from a vehicle crossing

Figure 6 shows the strain change rate (top), and bottom flange strain rate (bottom). From the strain change rate, there are five obvious events (shown via red shaded region) that coincide with

axle crossings. Based upon the pattern and spacing of these events, it can be concluded that the vehicle that crossed the bridge during this time period was a semi. This determination can be confidently made based upon the extensive database of vehicle configurations obtained from this and coinciding projects that provided vehicle geometry and load distribution.

This vehicle classification can then be confirmed via the captured images triggered by motion over the bridge from the same time period. Upon further investigation, the vehicle that crossed at this time was indeed a semi, as shown in Figure 7.



Figure 7. Semi corresponding to sample bridge response

As further validation, consider the case shown in Figure 8.

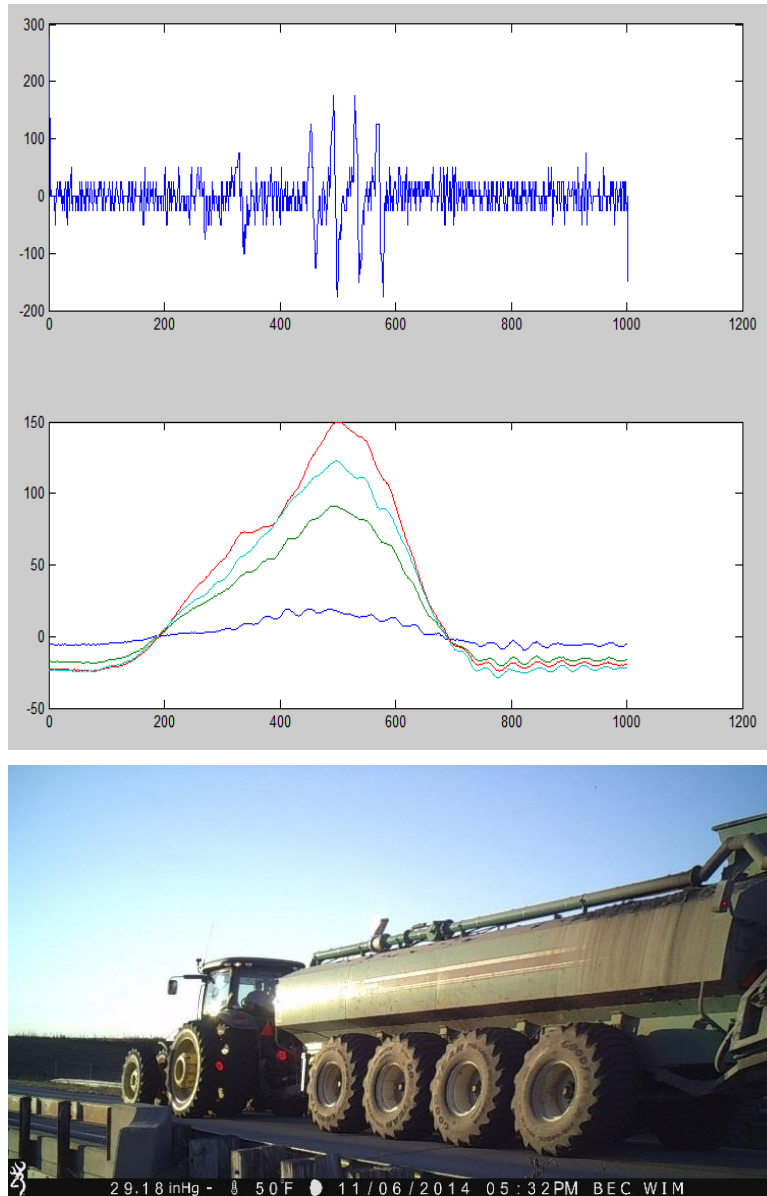


Figure 8. Honeywagon vehicle classification data

For this flagged vehicle, there are again key characteristics seen in the strain change rate graph that coincide with high strain induced in the girders. As such, the vehicle was considered of interest and based upon vehicle classification algorithms that were used for the semi case previously discussed, this vehicle was determined to be a honeywagon due to the axle crossing pattern. The techniques used to classify the semi and honeywagon in these two examples can be applied to all passing vehicles of interest, effectively determining the frequency and actual response of IoH vehicles based upon the database of vehicle geometries that has been established.

During the period of data collection, the many IoH vehicle responses that were captured also allowed for comparisons with standard load rating vehicles in terms of response. The maximum

strain levels from IoH did not exceed that of the loaded five-axle semi, except for the case of honeywagons. The seasonal trends of this vehicle can be seen when looking at maximum strain time history data. This plot is shown in Figure 9 and exhibits the large peak strains associated with honeywagons and the increase in frequency during the month of November, which corresponds to the end of harvest season.

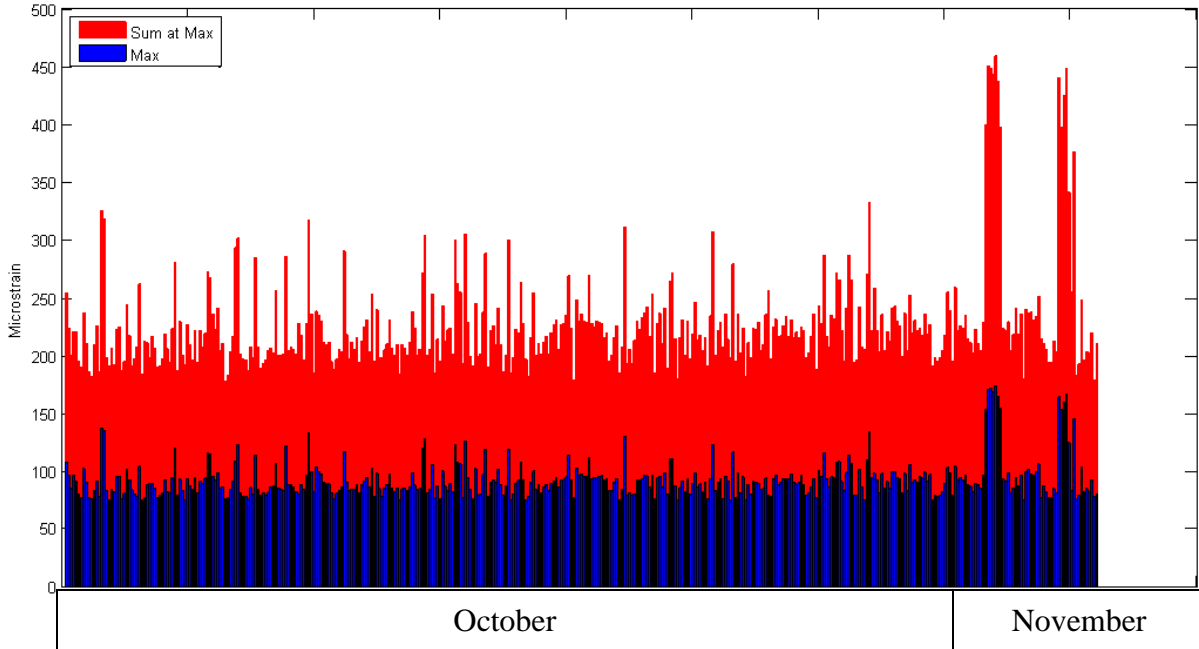


Figure 9. Maximum strain time history

CONCLUSIONS

The unique instrumentation setup, involving strain gages placed on the bottom face of the deck as well as on the top and bottom flanges of the girders, allows for the application of algorithms for vehicle classification determination. Using the maximum strain induced by a vehicle crossing, high strain-inducing vehicles of interest can be identified and classified into heavy and light IoH vehicles to allow for traffic demand classifications that are unique to the specific roadway. Further classification of the IoH vehicles is made possible by actual determination of specific vehicle type based upon strain response and the corresponding number and spacing of axles. This vehicle information provides actual loading and corresponding bridge response and, thus, maintenance decisions and actual structural demands can be properly selected based upon existing traffic types and frequencies. The system developed for this project can be deployed on rural bridges for realistic traffic classifications.

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