Multiple-Equation Bridge Weigh-in-Motion

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Summary

Weigh-In-Motion (WIM) systems are increasingly used to collect data on bridge traffic loading. A knowledge of load is an essential element in any calculation of bridge safety in service. Bridge WIM is the only accurate WIM technology that is portable. This gives it the potential to be used to assess loading on secondary roads where permanent installations would be uneconomic. This paper describes a multiple-equation Bridge Weigh-in-Motion (B-WIM) algorithm that significantly improves the accuracy of calculated axle weights using measured bridge strains. The algorithm is tested for a series of simulated two-axle vehicles crossing a bridge and the results compared to a conventional approach. The results show increased accuracy in predictions of individual axle weights on longer bridge spans, and no significant loss of accuracy in gross vehicle weight calculations.

Keywords: Bridge, Traffic, Load, Assessment, Bridge Weigh-in-Motion, WIM, B-WIM.

1. Introduction

With many of the world's bridges nearing the ends of their design lives, there is an increasing emphasis on safety assessment, maintenance and repair. If a bridge can be shown to be structurally safe, it can remain in service for a longer service life, which can lead to great savings in unnecessary repairs and replacements. In order to assess the safety of a bridge it is necessary to have a good knowledge of the loads which it is experiencing in service. This paper deals with Bridge Weigh-In-Motion (WIM), a method of weighing vehicles that pass over the bridge and hence of evaluating traffic loading on that segment of the road network. This paper discusses an algorithm which aims to improve the accuracy of the SiWIM Bridge WIM system.

2. Theory of Multiple-Equation Bridge WIM

The multiple-equation Bridge WIM algorithm uses multiple sensor locations along the length of a bridge and uses a least squares minimisation at each point in time between a measured strain signal and a theoretical strain signal for each sensor to solve for vehicle axle weights crossing the bridge. Carrying out this least squares minimisation leads to a solution in the form of equation (1):

$$\{A\}_k = [G]_k^{-1}\{C\}_k \tag{1}$$

where $[G]_k$ is an $n \times n$ matrix of influence line ordinates (n being the number of axles on the bridge at scan k) and $\{A\}_k$ is an $n \times 1$ vector containing the unknown axle weights. $\{C\}_k$ is an $n \times 1$ vector which contains products of measured strains and influence line ordinates for each sensor location.

The result is a time history of force predictions for the time during which the vehicle crosses the bridge. This differs from most conventional approaches as there is no longer a single prediction of the static load.

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3. Results & Discussion

A series of vehicle crossings on three different bridge spans (6, 12 & 20m) are simulated in Matlab. The results are compared to a conventional approach (Moses' algorithm). A 95% confidence interval is used to compare errors obtained from the multiple-equation algorithm to those obtained using Moses' algorithm (i.e., the width of the interval in which 95% of prediction errors will lie).

Fig. 1 shows the width of the confidence intervals for both algorithms (multiple-equation Bridge-WIM in blue and Moses' in red) for the three different bridge spans. The graph shows the single axle predictions (circles) and gross weight predictions (triangles). From Fig. 1 it can be seen than the prediction of single axles using the multiple-equation algorithm is better than Moses' for the 12m and 20m bridges but slightly worse for the 6m bridge.

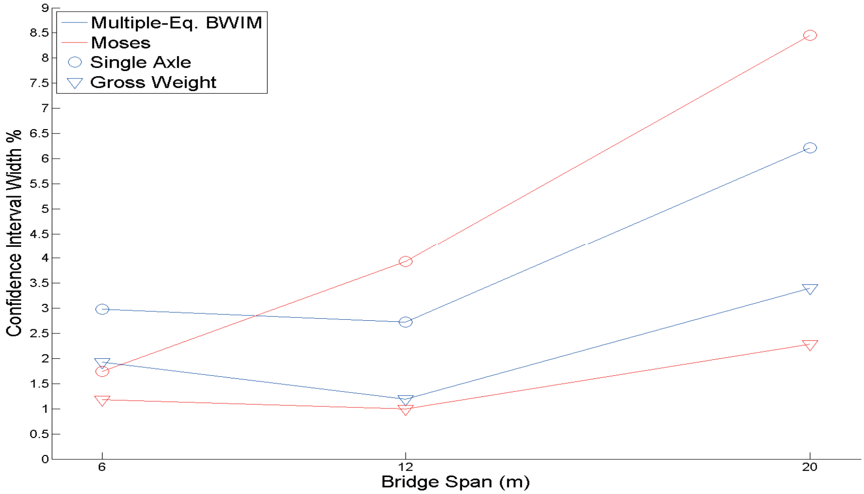

Fig. 1: Comparison of Multiple-Equation and Moses' Algorithms for Different Bridge Spans

The worst predictions, by both algorithms, occur on the longer bridge as would be expected due to higher ill-conditioning and increased dynamics. Here the single axle predictions by Moses' are within 8,5% while the multiple-equation algorithm improves these errors to 6,2%.

Gross weights tend to be predicted slightly less accurately than Moses' using the multiple-equation algorithm but are still very accurate (worst case = 3,4% for the multiple-equation approach on long bridge) and the slight decrease in accuracy using the multiple-equation algorithm is more than compensated for by its ability to improve single axle predictions on the longer spans.

4. Conclusions

In this paper a multiple-equation Bridge Weigh-in-Motion algorithm is described and compared to a conventional approach using simulated data. Results show than where the conventional approach becomes inaccurate, dropping to class B+ (7) on longer bridge spans, the accuracy of the multiple-equation approach remains within class A(5) accuracy. There is a slight but insignificant decrease in the prediction of gross vehicle weights using the multiple-equation approach. The algorithm presented in this paper provides promising results towards increasing the accuracy of current Bridge WIM systems.

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