Axle Load Monitoring of Multiple Vehicles Using Dynamic Bridge Responses

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Summary

A practical approach of axle load identification of multiple vehicles using continuous bridge bending moment is presented. Axle loads are identified using least squares regularization method via the updated static component (USC) technique in order to improve solution accuracy and calculation robustness. A parametric study considering effects of various characteristics of vehicles-bridge system including vehicle mass, moving speed, axle spacing, axle weight ratio, vehicle type and bridge surface roughness is performed. The experimental verification is carried out through a scaled model of vehicles/bridge system. Comparison on different schemes of moving characteristic including following movement and overtaking movement is also considered and discussed. The obtained results indicate that identification of vehicle axle load of multiple vehicles is very effective and robust for all moving schemes of multiple vehicle travel when the USC technique is applied.

Keywords: Weigh-In-Motion (WIM); multiple vehicles; axle load; bridge response; identification; parametric study.

1. Introduction

Dynamic axle loads of heavy weight vehicles are the important parameters for design and evaluation of bridges and pavements. Most of the past studies have been studied and scoped only in the case of single vehicle travel. However, in actual traffic there is frequent multiple presence of trucks on a bridge. Moreover using continuous bridges may be more appropriate to study longer time histories of vehicle loads and more convenient for a monitoring system installation. Therefore, the study of multiple vehicle axle load identification from continuous bridge response is presented via the parametric and experimental studies to investigate the effectiveness of the proposed method.

2. Moving Load Identification

Dynamic axle load identification of multiple vehicles from bridge response is numerically and experimentally studied. Based on the inverse problem, the time varying interaction forces between the vehicles and the bridge are determined from least squares optimization with regularization. The SVD method is adopted in the computation to provide robustness of the solution.

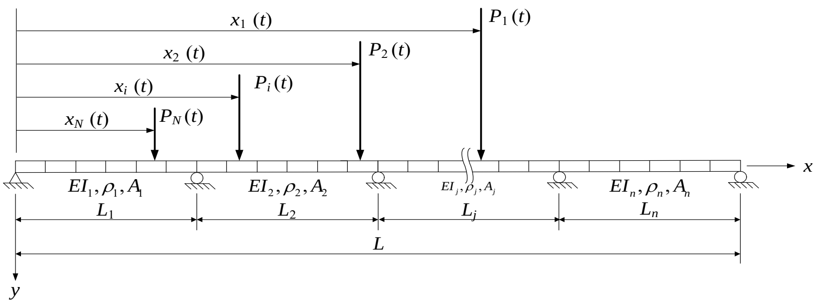

Fig. 1: An n-span bridge subjected to multiple moving loads

The updated static component (USC) technique is employed to enhance the accuracy of solutions. In iteration, the identified loads are decomposed to static and dynamic components. The extracted

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dynamic component will be re-identified while the static component will keep updating the iterative solution. With this procedure, the final solutions are highly enhanced in accuracy. Moreover, with this approach, the difficulty of dynamic load identification near bridge supports due to the weak relationship between loads and bridge bending moment is also eliminated.

3. Parametric Study of Multiple Vehicle Axle Load Identification

According to the results obtained from the parametric study, it is observed that vehicle having heavier mass and slower speed can be identified with higher accuracy than vehicles having lighter mass and faster speed. Vehicle with closely spaced axles and light weight performs poor accuracy compared to vehicle with wider spaced axles and heavier weight. Using bridge with smooth or very low surface roughness is highly recommended since the identification error is very sensitive and increases relatively to the higher level of roughness magnitude. Moreover, it is found that the proposed method is effective and robust for any vehicle configurations and possible travel situations.

4. Experimental Study Using Scaled Vehicles-Bridge Model

For the experimental study, the effectiveness investigation is made through the scaled vehicle-bridge model consisting of a three-span continuous bridge with two 2-axle vehicles models. The actual axle loads of vehicles are directly measured using load-cells. The obtained results reveal that the proposed method can accurately identify axle loads without significant distortion because axle loads are independently identified, corresponding to the USC algorithm. From the study on different vehicles travel scenarios, it is observed that the proposed method allows the relative percentage error within 10% for all vehicle moving schemes.

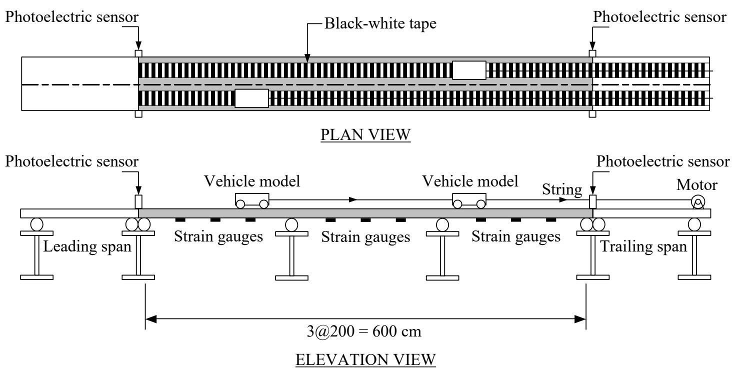

Fig. 2: Experimental Set-Up of Scaled Vehicles-Bridge

5. Conclusions

From the numerical and experimental studies, it can be concluded that the vehicle axle load identification from continuous bridge responses is very effective when the USC technique is adopted for the accuracy enhancement. The proposed method can be used for both single and multiple vehicles travelling on single or multiple span bridges for any vehicle configurations and moving scenarios. It is also expected that the proposed method is applicable to a practical systems designed to accurately identify multiple vehicle axle loads, and also able to be applied in practice.

6. References

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