Using Instrumented Quarter-Cars for 'Drive By' Bridge Inspection

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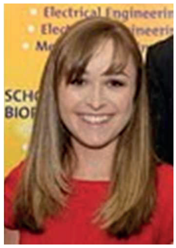

Summary

This paper investigates the concept of 'drive by' bridge inspection, a low cost alternative to Structural Health Monitoring (SHM), involving no sensors on the bridge. The concept may be of particular value after an extreme event, such as an earthquake or a flood, where a rapid indication of bridge condition is needed. Vehicle/bridge dynamic interaction is modelled to test the effectiveness of the approach. Damage is simulated here as a change in the bridge damping ratio. Two quarter-cars are simulated crossing the bridge with accelerometers on board. A frequency domain analysis then illustrates changes in the Power Spectral Density of the accelerations as the bridge becomes damaged. The time-lagged difference in the accelerations is found to be effective in detecting damage. Results are compared to those with sensors on the bridge and found to be similar.

Keywords: Bridge, damage, damping, dynamics, vehicle-bridge interaction, damage detection, drive-by.

1. Introduction

This paper describes a method whereby an instrumented vehicle is used to assess bridge condition. This approach, referred to as 'drive-by' bridge inspection [1], has advantages in terms of reduced cost and ease of implementation. Recent evidence suggests that damping is quite sensitive to damage in structural elements and more sensitive than natural frequencies [2]. Furthermore, many researchers note that damping can be a useful damage sensitive feature and is highly indicative of the amount of damage that a structure has undergone during its lifetime [3]. In this paper, an instrumented vehicle is used to detect changes in damping in a bridge.

2. Vehicle-Bridge Interaction Model and Bridge Response

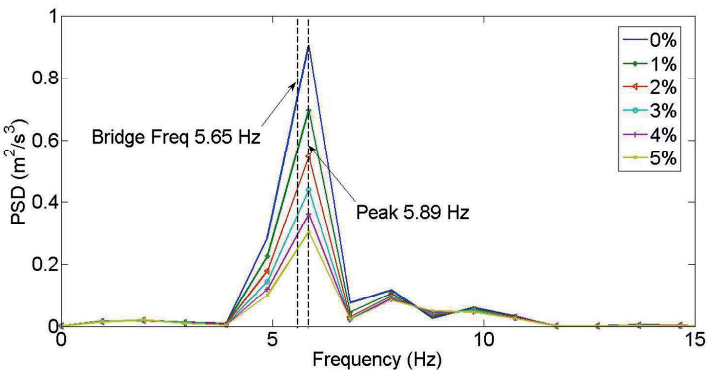

Fig. 1: PSD of the Difference in accelerations experienced by each quarter-car

The vehicle is represented by a pair of 2-degree-of-freedom unconnected quarter-cars, with identical properties. The spacing between each quarter-car is 2 m and they travel at a constant speed of 20 m s^{-1}, giving a constant spacing. The bridge model used here is a simply supported 15 m FE beam with a first natural frequency of 5.65 Hz. The road profile

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(Class ‘A’) is generated according to the ISO standard [4]. A 100 m approach length is included in the road profile prior to the bridge.

Accelerometers are placed on the axles of the two quarter-cars, which are simulated travelling at 20 m s^{-1} over the bridge. The excitation of the vehicle at any point in time consists of the bridge deflection under the axle and the road profile height. The accelerations of both quarter-cars are subtracted from one another, allowing for the time shift. This has the effect of removing the road profile heights and leaves the difference in accelerations. The acceleration signal is transformed into the frequency domain and the Power Spectral Density (PSD) plots for each level of bridge damping can be seen in Fig. 1. A peak can be detected at the bridge frequency, and the magnitude of the peak decreases for higher levels of damping. This suggests that a pair of identical instrumented vehicles have the potential to be a practical method of detecting changes in PSD which then may be used as an indicator of changes in bridge damping and ultimately as an indicator of damage.

3. Discussion and Conclusion

Results from simulating sensors on the bridge indicated that the bridge frequency can be detected when the bridge was excited. Separately when the accelerometers are placed on the axles of the vehicles, results indicate that the bridge frequency can be detected here also. A frequency domain analysis illustrates that changes in PSD as the bridge becomes damaged can be detected – confirming that bridge damping can be detected using a drive by vehicle. Results using sensors on the vehicle are found to have a similar level of accuracy as those found using sensors on the bridge.

4. References

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