**Understanding Vehicle-Bridge Interaction through Field Measurements and Model-Based Simulations**

**PhD Dissertation by:**

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**Abstract**

Although the qualitative and empirical approaches that define today’s bridge engineering practice have served the profession well over the past five decades, they are wholly incapable of operating under the current fiscal pressures or answering the calls for more efficient and transparent resource allocation. Principal among the shortcomings of current design and assessment approaches is their inability to accurately address the effects of trucks (perhaps the largest demands bridges experience) on the dynamics of the coupled vehicle-bridge system (vehicle-bridge interaction) and consequently on bridge performance. Furthermore, this lack of understanding represents a key barrier to meeting the needs of emerging connected vehicle technology, specifically truck platooning. Truck platooning, which involves virtually connecting trucks into a train with extremely small headway between vehicles, not only drastically changes the level of live load on bridges, but it also creates a more steady-state dynamic loading that cannot simply be accounted for with an amplification factor.

A roadway profile, on and off the bridge, serves to induce vertical oscillation in a vehicle. That oscillation results in an oscillating force at the point of contact between the vehicle and roadway. As the vehicle crosses the bridge, the contact force excites the mass of the bridge. Vehicle and bridge parameters therefore effect dynamic amplification based on their influence on the dynamics of the system and how those system dynamics relate to the profile characteristics.

In order to better characterize the role of parameters on bridge dynamic response, an inductive approach was adopted whereby a structure exhibiting large dynamic responses was investigated using the Structural Identification (StId) framework. Field testing of this structure was performed to obtain measurement of operational responses. These responses provided quantification of the bridge’s dynamic behavior and provide data to inform and “calibrate” FE models, thus ensuring that the models could accurately simulate VBI.

A simplified VBI model is proposed that reduces the bridge to a single degree of freedom with generalized coordinates according to a shape function that describe the first mode of bending for a beam. The performance of the simplified model was assessed by comparing predicted amplification factors to those predicted by validated 3D FE simulation methods. The simplified models were found to perform relatively well and yields conservative estimates of amplification factors.

Simulations were also performed to characterize the influence of bridge, vehicle and profile parameters on bridge dynamic amplification. The results of these simulations indicate that bridge responses are greatest when the profile induces oscillation in the vehicle close to the bridge’s natural frequency and when the vehicle’s natural frequency is 10-20% greater than that of the bridge. Furthermore, the roughness of a profile has a great impact on dynamic amplification. The effect of the profile is dependent on both transient and harmonic features. Therefore, the profile position and phase angle distribution of harmonic content cannot be ignored.