# **Abstract**

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

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Current design and assessment approaches fail to 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, which involves virtually connecting trucks into a train with extremely small headway between vehicles.

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.

Rolling straight-edge requirements were examined through simulation studies to determine their effectiveness at reducing dynamic amplification. Common straightedge lengths of 10 to 16 feet fail to remove content that induces low frequency oscillations in the vehicle. Rolling straightedge requirements should therefore specify a length of at least 30 feet and a deviation limit of ¼ inch or smaller.

VBI simulations were performed for traffic and truck platoons. The number of vehicles in the platoon and the spacing between vehicles was principally investigated. From these studies it was found that traffic and truck platoons can result in increased dynamic amplification because even a single previous truck can induce the bridge conditions (motion) that result in increased dynamic response. As spacing between vehicles decreases and more vehicles are present on the bridge, the static load effect increases, but the dynamic amplification will be no greater than what would occur for a single vehicle.