Running Safety of a High-Speed Train Through a Multi-Span Bridge under a Non-Uniform Moderate Earthquake

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Abstract

The train-track-bridge system is significantly excited, even by a moderate earthquake. Therefore, the running safety of the train under an earthquake should be studied to prevent the derailment during its operation. This work investigates the running safety of a high-speed train moving through a multi-span bridge and excited by a non-uniform moderate earthquake. The track-bridge system is modelled by three-dimensional finite element method. Each train vehicle has 27 degrees-of-freedom and is described by the rigid bodies linked by suspensions. The stationary random track irregularities are generated using the empirical one-sided power spectral density functions. The non-uniform seismic excitations are applied to the bridge piers using the large mass method. The derailment factor and the offload factor is used to evaluate the running safety of the train.

Keywords: high-speed train; running safety; railway bridge; non-uniform seismic; dynamics.

1 Introduction

The high-speed railway is fast developing in the world. The probability of a train encountering an earthquake when it is running through a bridge increases significantly. An earthquake produces strong excitations to the train-track-bridge system and enlarges its dynamic responses and is a threat to the running safety of the train. Thus, the dynamic responses of the train over a bridge under an earthquake should be analyzed to ensure the safety during its operation.

A realistic model of the train-track-bridge system is required to analyze their dynamic responses under seismic loads. As seismic waves are varying spatially, the train-track-bridge model must be a three-dimensional one. Finite elements are used to model the track and bridge; rigid bodies connected by suspensions with 27 degrees-of-freedom (DOFs) described each vehicle on a train. The self-excitation in the train-track bridge system includes the random track irregularities, which is generated from their power spectral densities, and the hunting motions of the wheelsets. The motions of the wheels depend on the motions of the rails, which is also called the motion constraints. Though the motion constraints, the dynamic wheel-rail contact forces are obtained, and the equation of motion (EOM) of the train-track-bridge system is derived.

While the train is moving over the bridge, and an earthquake may happen. In this case, the dynamic responses of the train need to be analyzed, and its running safety should be considered. Some researchers considered the seismic load according to the consistent seismic excitation method, which considers the train-track-bridge system is excited simultaneously. However, the seismic waves propagate through the rock and soil and arrive at bridge piers at different times, and different bridge spans are excited asynchronously. Hence, this

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