An efficient vehicle-bridge interaction framework for massive traffic

HAN Zhuoran

Keywords: vehicle-bridge interaction, finite element analysis

【Background】

The vehicle-bridge interaction (VBI) describes the direct coupling between the viaduct systems and the vehicles traveling on it. It is a key to studying the structural integrity of the viaduct and the driving safety and comfort of the vehicles. Recent studies related to VBI mainly use commercial finite element analysis (FEA) software or platforms which are powerful and precise, however, they are inflexible for time-variant dominant systems with relatively simple models, such as the vehicle-bridge interaction system.

【Objective】

The objective of this research is to propose a method, in terms of a framework, that is optimized for vehicle-bridge interaction system simulation, which is fast, convenient, and versatile, and is potentially capable of conducting simulations of a large VBI system as close to reality as possible.

【Methodology】

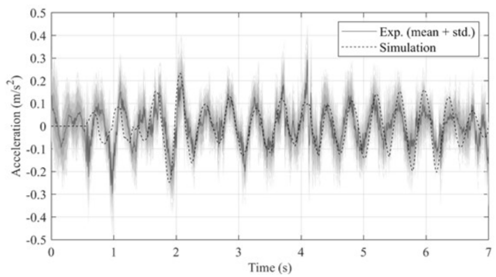
In this study, an efficient and versatile solution is proposed as a framework for the simulation of large viaduct systems considering VBI. The framework consists of a dozen self-written scripts in MATLAB and is based on the finite element method (FEM) using the Newmark-beta method for direct integration. It integrates several new ideas, self-written algorithms and optimizations to improve efficiency and versatility.

【Publication plan】

令和3年度全国大会　第76回年次学術講演会

【Verification】

The framework is verified with a laboratory experiment. Results show great agreement between simulation result and experiment data.



Vehicle acceleration time history

Solid line: experiment average

Gray area: ±1-3 standard deviation

Dashed line: simulation result

【Application】

The framework is tested with a large VBI case with a 1,050-meter bridge and 224 vehicles. The simulation with 100,000 time-steps finished in three hours with an intel i9-9900K computer. The fully coupled (non-iterative) approach and the segregated (iterative) approach are also compared and discussed. Results show that both approaches are applicable, in terms of either time cost or accuracy. More importantly, the time cost of the VBI simulation is linearly related to the total degrees of freedom (DOF) of the system, thanks to the code-level integration of sparse matrices. As a result, the framework can handle simulations of large VBI systems with further improvements in the future.