Research Project Highlight

A Systematic Computational Framework for Multi-span Bridge PBEE Applications

Project #1138-NCTRGA

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Abstract
In this project, an integrated computational framework is developed to combine nonlinear Time History Analysis (THA) of multi-span bridge systems with an implementation of the PEER PBEE methodology that estimates the probabilistic repair cost and repair time. In addition, the carbon footprint of repair will be included as a sustainability metric in this framework. This research builds on previous efforts including a PBEE assessment tool BridgePBEE (developed by the PI and co-workers under an earlier PEER-funded project) and the THA multi-span bridge-foundation framework MSBridge (using OpenSees, developed under a Caltrans-funded project, as shown in *Project Image a*). In the nonlinear THA, bridge columns/piers are modeled using Force-based beam-column elements with a nonlinear Fiber section. Advanced abutment models considering bearing pads and shear keys are also included. Bridge columns/piers, superstructure, abutments, and foundation response mechanisms are integrated within a unified framework. Systematic evaluation of the global system response is conducted under a wide range of earthquake input shaking scenarios. The analysis options available in the new user interface MSBridge include: i) Pushover analysis; ii) Mode shape analysis; iii) Single and multiple 3D base input acceleration analysis; and iv) Full PBEE analysis (*Project Image b*). All stages of the involved analyses including the PBEE assessment are executed in a systematic fashion, allowing the end user to conveniently conduct extensive parametric investigations. An important feature of the new interface is that the PBEE analysis can be executed sequentially: i) ground motion selection, ii) THA, iii) loss (repair cost, time and carbon emission) modeling, and iv) calculation of hazard curves. Once the time history results are computed, the user can view the PBEE results against any Intensity Measure (IM) and perform what-if scenarios by changing any parameter of the intermediate probabilistic models without recomputing the time history results.

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Deliverables

The main deliverables include:

i) A computational modeling tool estimating PBEE outcomes include repair cost and repair time, as well as the carbon footprint of repair.

ii) A user manual for conducting extensive parametric studies using the modeling tool.

iii) Example problems of multi-configuration bridge systems (for a wide range of expected earthquake input shaking scenarios).

Research Impact

Seismic response and failure mechanisms of highway bridges, which are critical lifelines in a transportation network, continue to receive much research attention. Tools and guidelines that allow bridge engineers to use nonlinear THA as well as PBEE for design/assessment of ordinary bridges will improve safety and mobility across California and enhance the performance of bridges in seismic events. This project will develop an integrated computational framework for combining nonlinear THA of multi-span bridge systems with PBEE assessments that estimate the probabilistic repair cost and repair time. In addition, the carbon footprint of repair will be included as a sustainability metric. The integrated computational tool will allow bridge engineers to efficiently conduct nonlinear THA studies with PBEE assessments for a wide range of multi-span bridge configurations within a seamless integrated simulation environment. On this basis, the bridge engineers can compare the effectiveness of different bridge design options and evaluate the performance of bridges. In addition, this research project will provide the stake-holders with a valuable tool that contributes to economic-based and environment-based decision making. The project builds on prior PEER research to integrate research outcomes into robust next generation seismic computational assessment tools for bridge systems. The framework can also incorporate the latest research outcomes from other related PEER work when available (e.g., an advanced abutment/shear-key model, or an updated PBEE-type framework).

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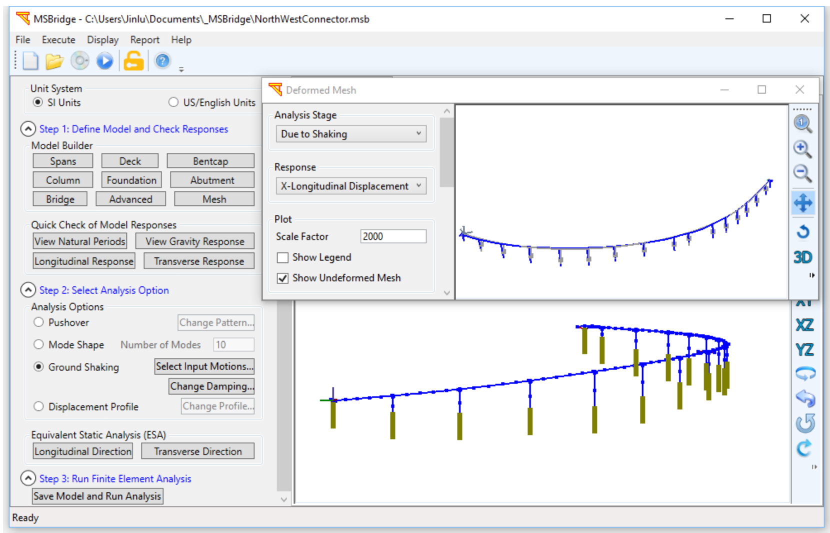
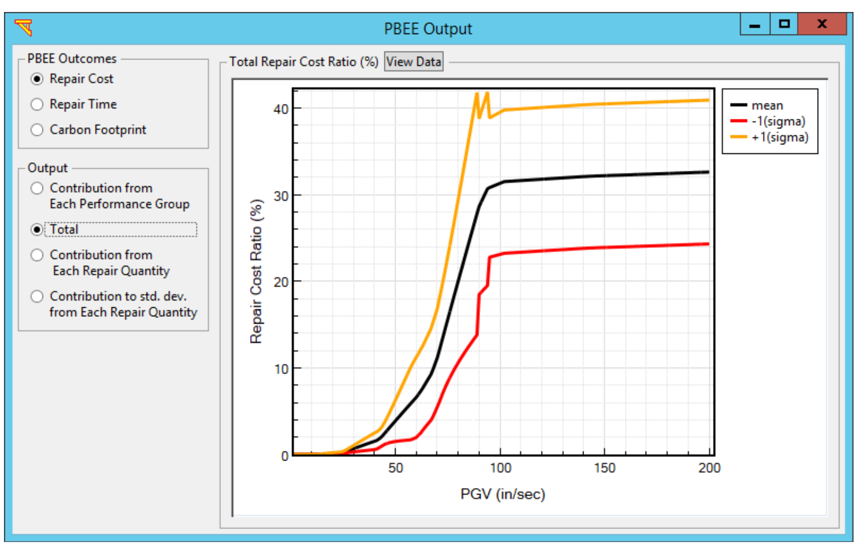
Project Images



(a) MSBridge user interface with mesh showing a highway connector curved bridge with pile foundations (top-right window shows a sample deformed mesh due to earthquake shaking)



(b) PBEE outcomes reported in MSBridge user interface

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