Research Project Highlight

Probabilistic Simulation-Based Evaluation of the Effect of Near-Field Spatially Varying Ground Motions on Distributed Infrastructure Systems

TSRP Topic – Methodology – M1

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Start-End Dates:
April 2020-March 2022

Abstract
The proposed project will provide a simulation framework for performing probabilistic risk-informed analysis of distributed systems. The application portion of the study focuses on the potential damaging effects of long-period displacement pulses, permanent ground displacements and spatially variable ground motions on the nonlinear seismic response of long-period transportation systems. Simulated ground motions from physics-based wave propagation models will be utilized for performing site-specific evaluations of the earthquake risk to major distributed infrastructure. This approach will assist in overcoming the limitations imposed by the sparse existing observational database of near-field ground motion records and building a statistically significant basis for developing a full understanding of the variability of the demand posed to distributed systems. The subject of the study will include long-span bay crossing bridges residing in the San Francisco Bay Area.

The project will start with the investigation of a suite of simulated ground motions obtained from multiple M7 scenarios, providing a measure of the potential variability of the demand generated by the same fault-rupture, *Project Image a)*. This investigation will be primarily aimed at building confidence in the use of simulated ground motion records for engineering applications. Concurrently, a representative numerical model of a long-period bridge will be developed to perform multi-support ground motion excitation analysis, with the inclusion of uncertainties associated with structural properties, *Project Image b)*. Analysis of the ground motion features that mostly influence the nonlinear structural response of long-span structures residing in the vicinity of an active major fault will be conducted. Comparisons with the structural performance obtained with the classical Probabilistic Seismic Hazard Analysis (PSHA) approach will be also developed, *Project Image c)*. The proposed research is expected to shed new light on probabilistic evaluation of the variability of the seismic risk

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posed to distributed infrastructure and inform earthquake performance-based infrastructure design and evaluation.

Deliverables
A PEER report and conference and journal papers describing the methodology adopted for the analysis of the simulated ground motions, the numerical model of a long-span bridge that includes uncertainty quantification, and the impact of using site-specific ground motion to the evaluation of the seismic risk posed to distributed infrastructure systems.

Research Impact
Traditional approaches to earthquake structural risk evaluation rely on Probabilistic Seismic Hazard Analysis (PSHA), whereby the potential damage of a particular structure is evaluated from fragility functions and hazard curves derived based on an ergodic assumption of earthquake processes. Although widely employed, this methodology does not fully account for the potentially large site-specific variability of the demand for sites in the vicinity of a major fault nor the sensitivity of structural response to specific ground motion characteristics that are not represented by hazard curves. Leveraging the use of a statistically significant database of simulated broadband ground motions and advanced structural model simulation tools will provide new understanding of the influence of ground motion spatial variability on long-period distributed systems. Covering a broad range of frequencies and ground motion features represents a key aspect for the analysis of long-span bridge structures, which can exhibit very low frequencies (0.1Hz to 0.05Hz) associated to the long wavelength modes of the deck system and relatively high frequencies associated to the vibration of the bridge towers (5 to 8 Hz). While work is being conducted on the use of simulated ground motions (1 Hz resolution) for structural response analysis, the proposed research will adopt a suite of fully validated simulated broadband records to represent the site-specific demand on the structural systems with associated probability of occurrence and structural systems models that include uncertainties. The proposed research addresses a topic of high interest to the scientific and engineering community and can inform infrastructure design and evaluation on a risk-informed basis.

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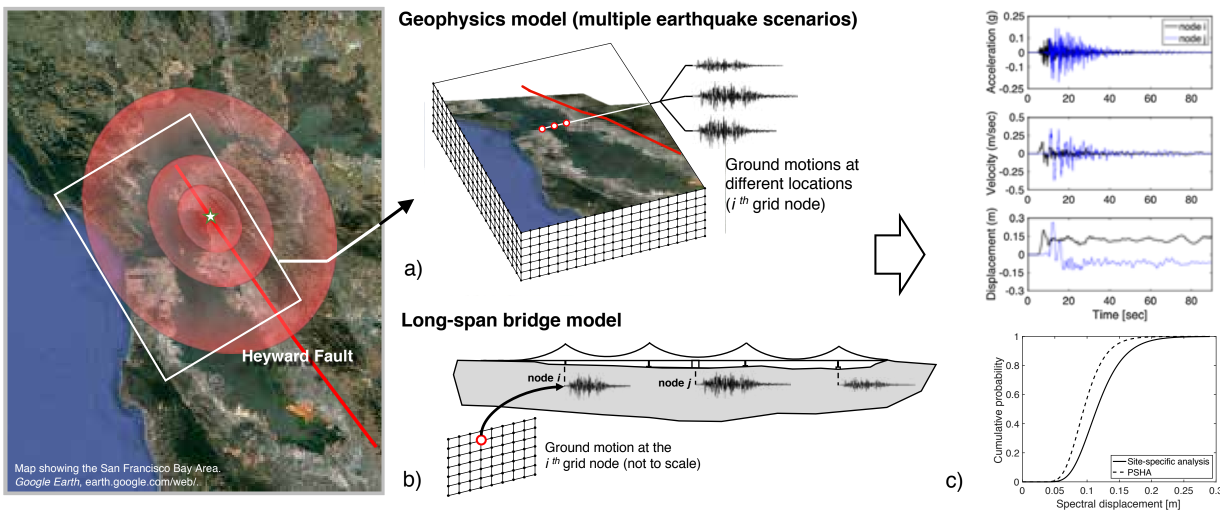
Project Image



a) Geophysics model of the San Francisco Bay Area b) Representative long-period bridge c) Demonstrative model results for the evaluation of seismic risk variability

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