Impacts of CyberShake on Risk Assessments for Distributed Infrastructure Systems

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Objectives

Empirical ground motion models (GMMs) are typically used to quantify spatially correlated ground motion hazard in current seismic risk modeling for spatially distributed systems. They represent "average" source, path attenuation, and site response characteristics of global earthquakes, and have large variability reflecting a variety of crustal structures and conditions. Such differences for a specific region can lead to poorly centered and wider than necessary distributions of the risk metrics.

The SCEC CyberShake platform is designed as the first physics-based seismic hazard model to address the need for regional assessment of ground motions. The platform simulates over 500,000 earthquake ruptures and propagates waves through 3D velocity models. Provided that the simulations have been properly validated, they should, in theory, include the source, path and site effects of a specific region.

In this study, we build on a recent GMM-based Probabilistic Seismic Risk Analysis study of the underground water pipeline network for the City of Los Angeles, where the system-level risk, measured by the expected number of pipeline repairs, repair cost, and repair time, was established as a function of exceedance probability from a large set of earthquake simulations using the NGA-West2 GMMs. We repeat our study using the events and simulations from CyberShake and explore the impact of region-specific simulations on seismic risk assessments of distributed infrastructure.

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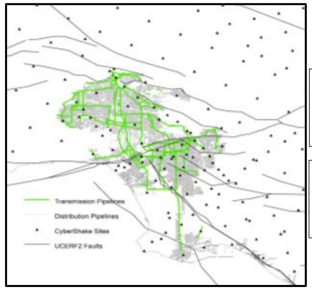
General Technical Approach for Pipeline System Risk Assessments



LADWP's water transmission (green lines) and distribution (dense grey lines) pipelines. Dots are CyberShake recording stations

GIS data for pipelines

Pipe fragility models

Perform event simulations based on UCERF3 to construct a stochastic event catalog ("Event-set") that is consistent with regional seismicity

For each event simulation, construct spatially correlated random ground motion map based on empirical GMMs, as well as ground displacement from soil liquefaction, landslide, and fault surface rupture

Calculate no. of pipe repairs for each pipe alignment and aggregate throughout network

Construct system-level risk curves (expected number of of pipe repairs, repair costs & repair times) as a function of return periods

Perform risk de-aggregation by rupture scenarios, hazards, major alignments, etc., to identify risk drivers and mitigation priorities

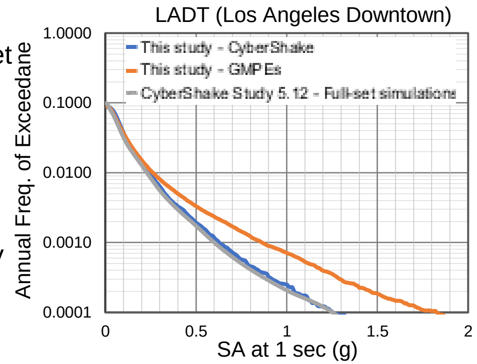
Lee et al. (2019)

Procedures of Computing the System-Level Risk of a Pipeline System Using CyberShake and GMMs

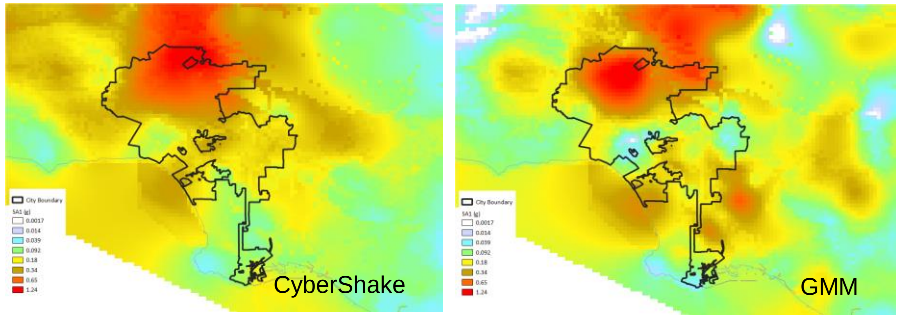
- Construct a stochastic event set from CyberShake Study.
- Construct a pair of stochastic ground motion intensity maps (CyberShake and GMMs) for each event in the event set. Intensity maps produced by GMMs also consider spatial correlation of ground motion (Loth and Baker, 2013).
- Apply the pipeline fragility models developed in Lee et al. (2019).
- Construct and contrast the system-level risk curves from CyberShake simulations and GMMs.

–Seismic hazards calculated using the stochastic event set constructed in this study match those from the full set of CyberShake simulations

–At low probability levels, seismic hazards calculated using GMMs are significantly higher than those from CyberShake simulations

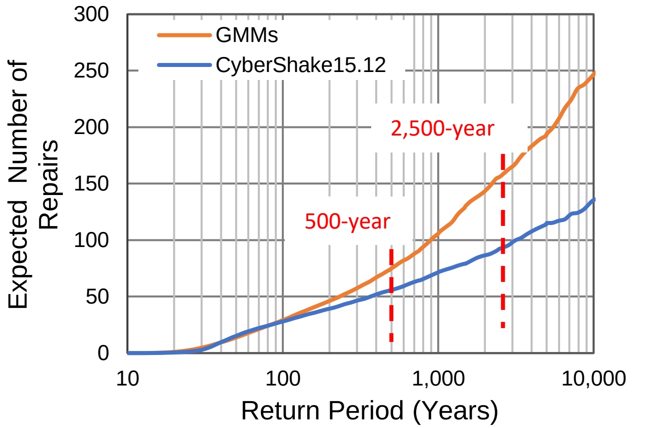


Examples of Scenario Intensity Maps (Sierra Madre M6.95)



Results

Pipeline System-Level Risks: Trunk-Lines, Shaking-only



Conclusions

– The total length of the LADWP's trunk line network is about 400 miles and it covers a wide area of Los Angeles. The system-level risks computed from CyberShake15.12 simulations and empirical GMMs are similar for shorter return periods (< 100-year) and show significant differences in longer return periods. Specifically, system-level risk computed from CyberShake is about 26% lower than that from GMMs at a 500-year return period, and about 41% lower at a 2,475-year return period, respectively.

– The difference may result from region-specific median attenuation, variability, and spatial correlation of ground motion of the two methods. Further research will focus on these important seismic wave characteristics as well as a characterization of the proxy metrics used, for better understanding the differences in results when the two methods are applied to risk assessments of spatially distributed systems.