Impacts of an M9 Cascadia Subduction Zone Earthquake on RC Core Wall Structures in Deep Sedimentary Basins

University of Washington / Nasser Marafi, Andrew Makdisi, Jeffrey Berman, Marc Eberhard

Background and Motivation

• The Cascadia Subduction Zone (CSZ) is capable of producing an M9 earthquake that causes long-duration shaking in the Pacific Northwest (PNW).

• The Puget Sound region is underlain by a deep sedimentary basin that is known to amplify the long-period ground-motion frequency content.

• The USGS estimates that an M9 CSZ earthquake has a 500-year return period with a 10-14% chance of occurance in the next 50 years.

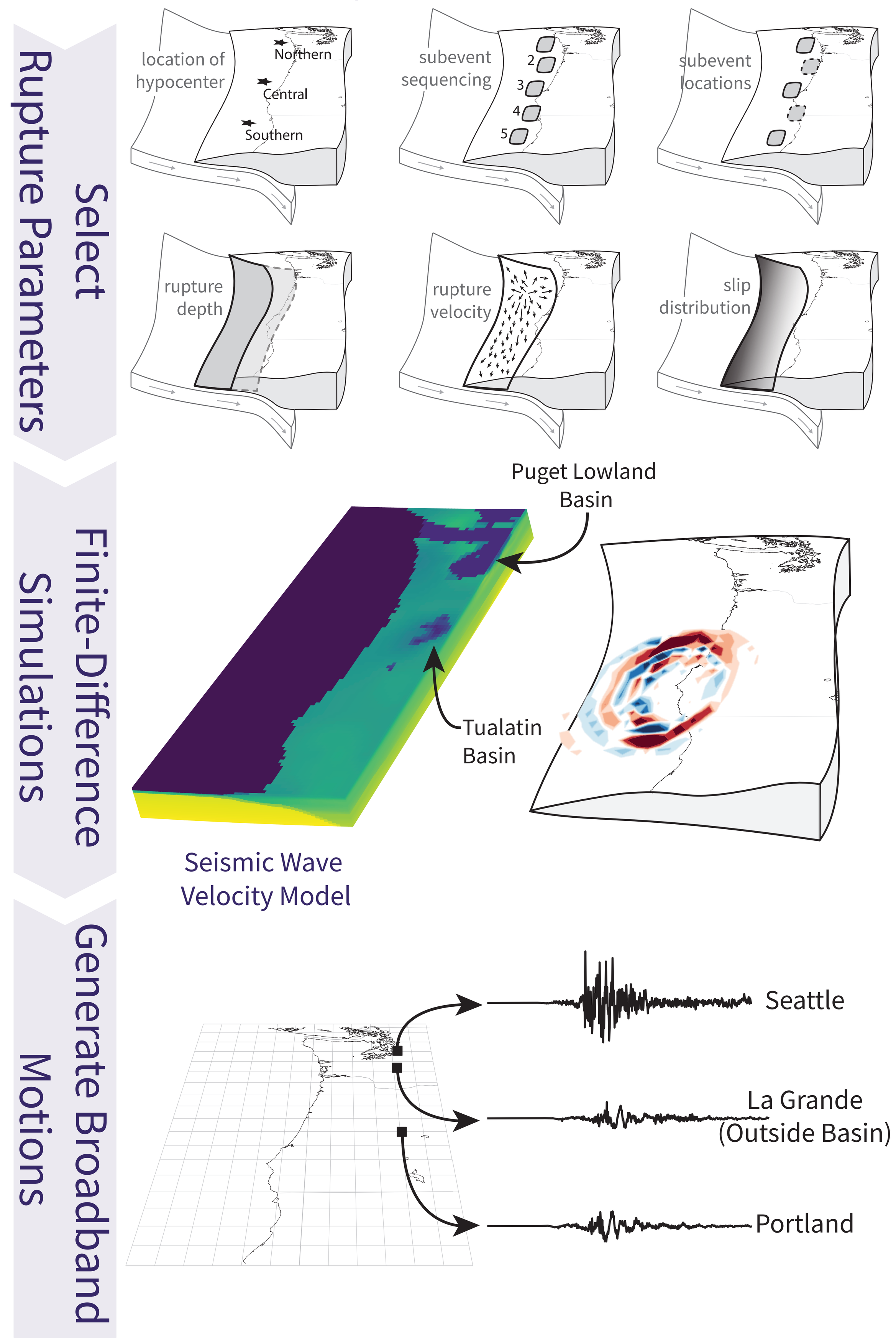
• The impacts of an M9 CSZ earthquake on buildings in the PNW is largely unknown because there are currently no recordings of an M9 earthquakes in the region.

Objectives

• Study the impact of an M9 CSZ earthquake on a suite of buildings in Seattle using (1) ground-motions derived from physics-based simulations and (2) numerical models that capture the structure's non-linear reponse.

Physics-Based Simulations

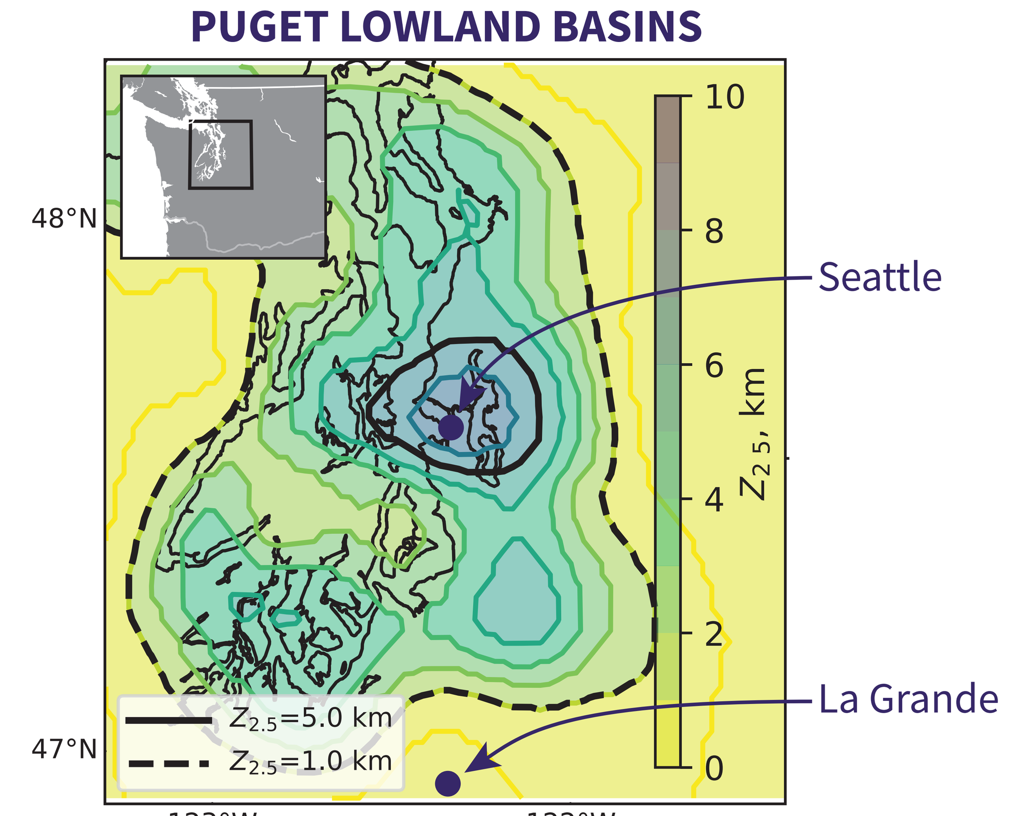
• Frankel et al. (2018) generated over 30 realizations of an M9 CSZ scenario which are largely based on the logic trees that make up the National Seismic Hazard Maps.



Deep Sedimentary Basin

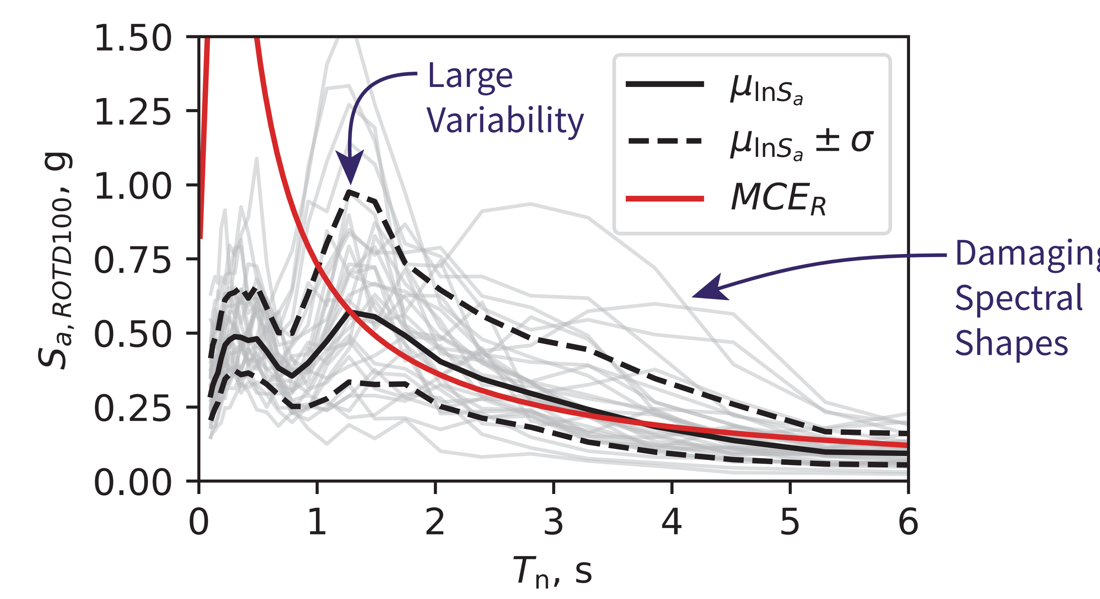
• Tall buildings in Seattle are founded on glacially compacted till with a shear-wave velocity reaching up to 500 m/s near the surface.

• Hard rock with shear-wave velocity equal to 2,500 m/s is around 8 km below the city of Seattle.



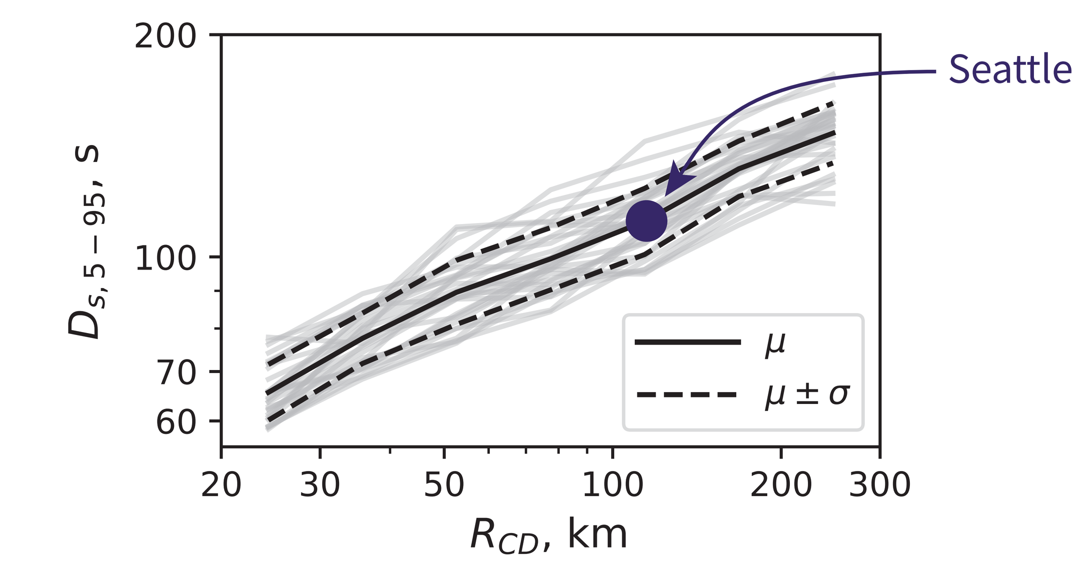
Spectral Acceleration

• Median spectral accelerations from an M9 CSZ earthquake is found to be larger than the MCE_R for periods between 1 to 3s.



Ground Motion Duration

• The 5-95% Significant Duration ($D_{s,5-95}$) was found to increase with closest distance to rupture (R_{CD}) and is around 120 s long in Seattle.

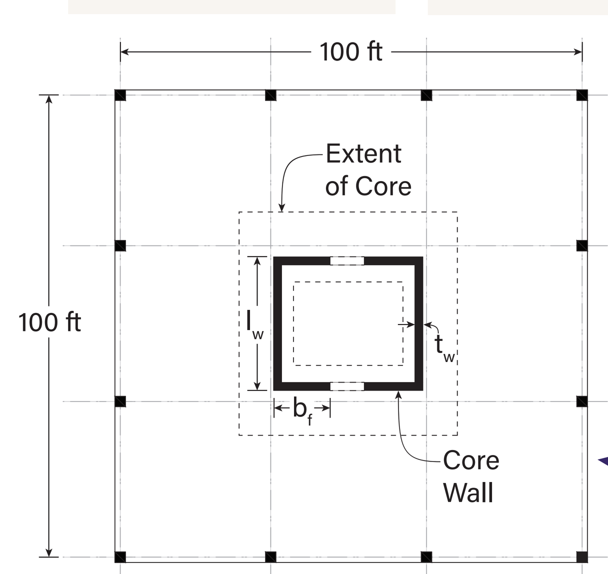


Archetype Development

• The impacts of the M9 CSZ motions on building response were assesed using a suite of archetypes that were developed with engineering firms in Seattle through collaborative efforts with the Structural Engineering Association of Washington.

–Downtown Seattle –Modal Analysis (MRSA)
–R=6, I=1.0 –Site V_{S30} = 500 m/s

	H < 240'	H ≥ 240'
ASCE 7-10	USGS 2008 NSHM 85% ELF Base Shear	Tall Building Initiative Guidelines
ASCE 7-16	USGS 2014 NSHM 100% ELF Base Shear	

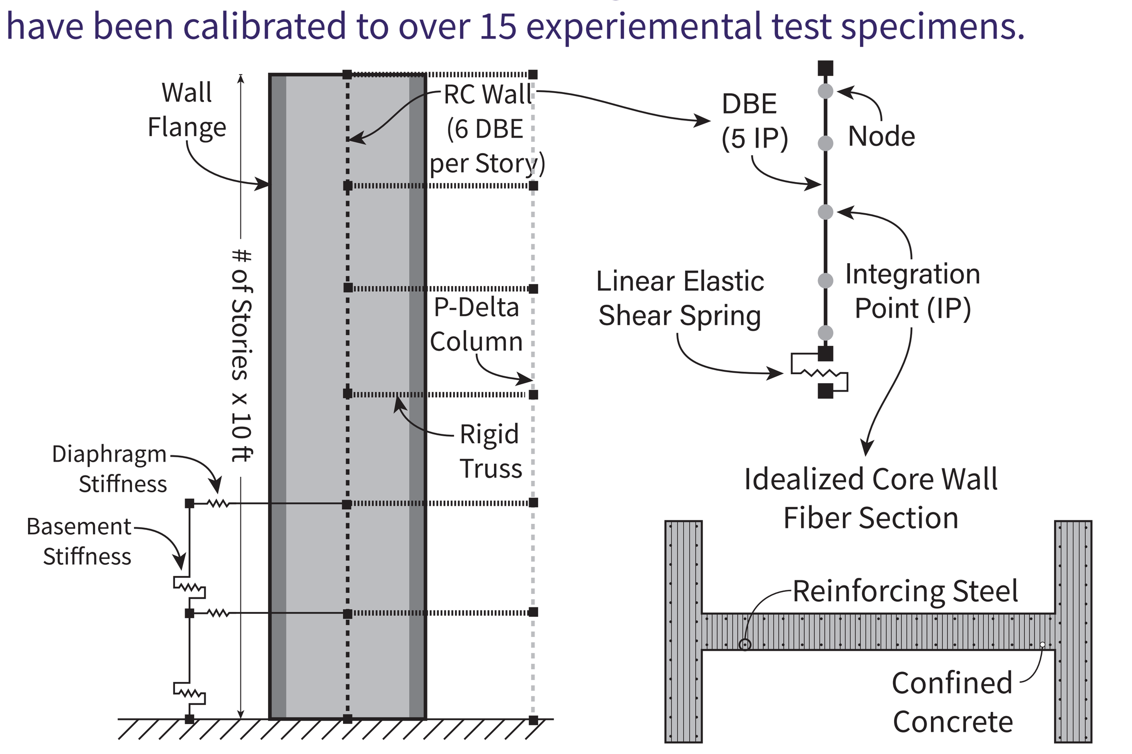


Archetype Properties:
- 10' floor-to-floor height
- 2-4 basement Levels included
- 130 psf + Core Weight
- f_c = 8 ksi for core, 5 ksi elsewhere

Typical Story

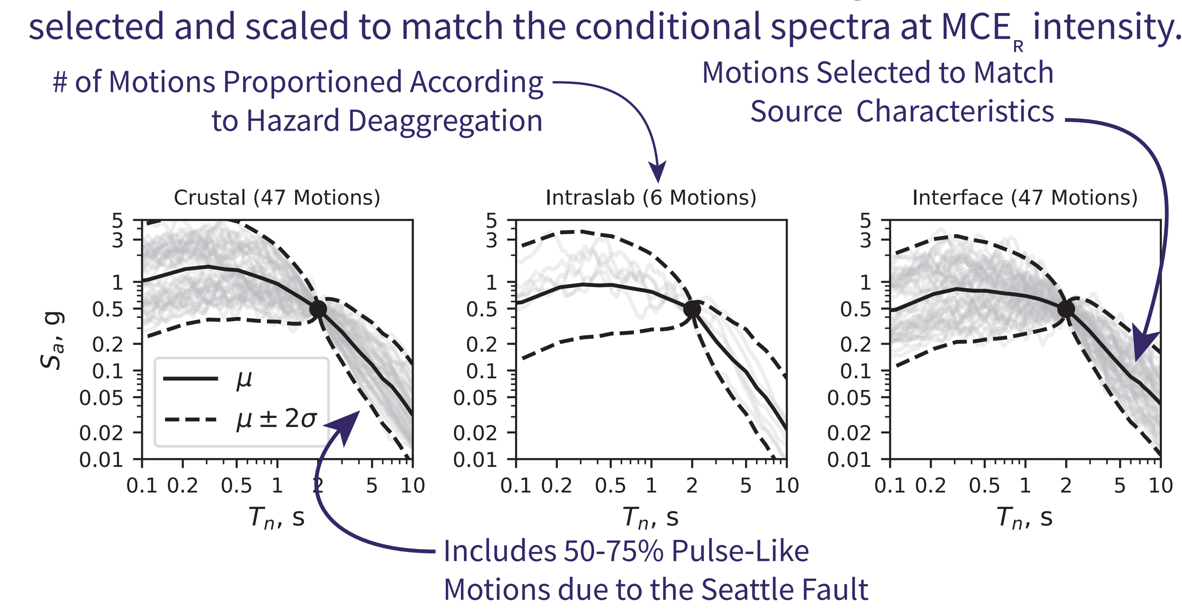
Modeling

• The earthquake response of RC core walls is idealized in a 2-dimensional OpenSees model using non-linear material models that have been calibrated to over 15 experiemental test specimens.



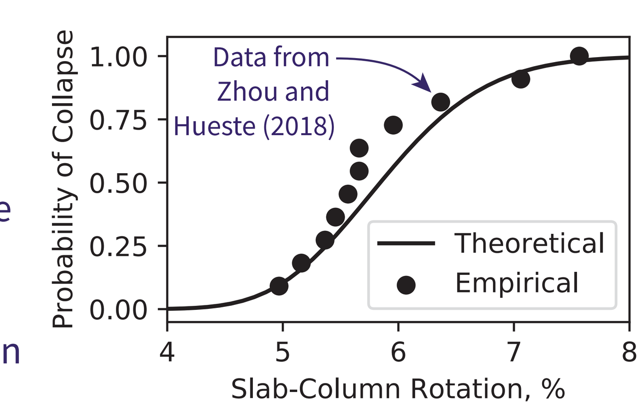
MCE_R Conditional Spectra

• The engineering demands of each archetype under an M9 CSZ earthquake are compared to those expected from ground-motions selected and scaled to match the conditional spectra at MCE_R intensity.



Structural Collapse

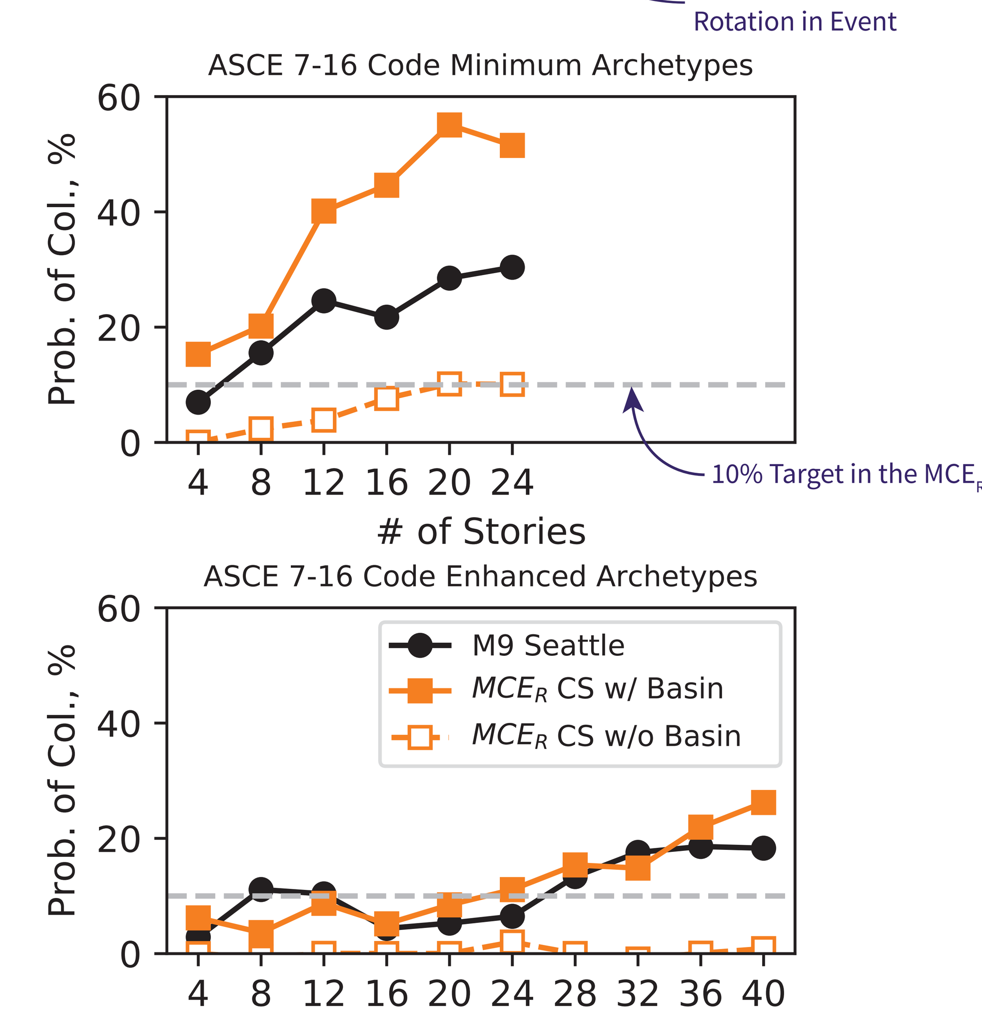
• The structure's collapse susceptibility was determined using the maximum rotation drift demands of the slab-column connections. The likelihood of slab-column connection failure was determined using a collapse fragility that was generated using experimental data of the the drift capacity of PT slabs with shear stud reinforcement and gravity shear ratio between 0.4 to 0.6.



• The probability of collapse under an earthquake event can be computed using the equation below:

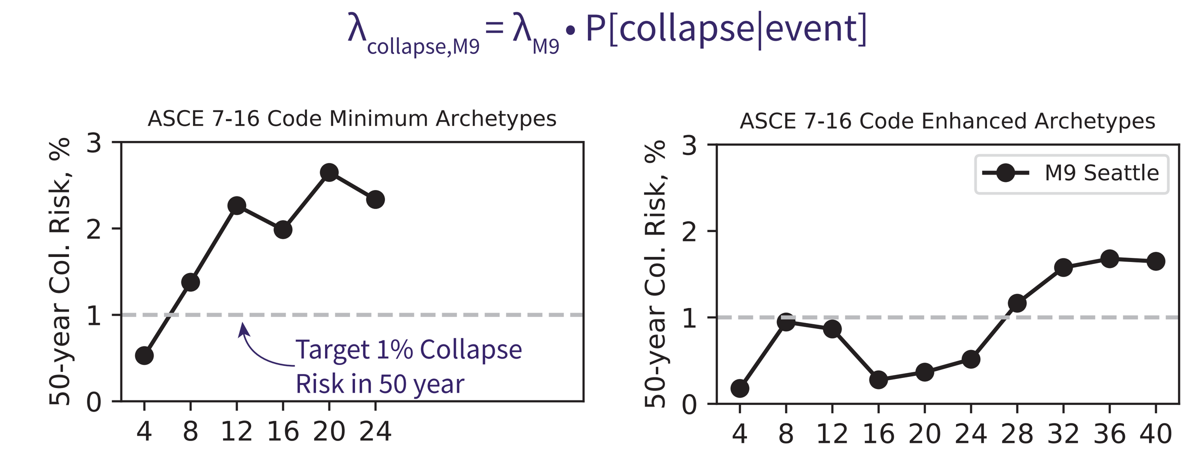
$$P[\text{collapse}|\text{event}] = \Sigma_{i=1}^{N} P[\text{collapse}|SCR_i] \cdot P[SCR_i|\text{event}]$$

Max. Slab-Column Rotation in Event



• Considering the 500-year return period of an M9 CSZ earthquake, the annual collapse risk can be computed as:

$$\lambda_{collapse,M9} = \lambda_{M9} \cdot P[\text{collapse}|\text{event}]$$



Conclusion

• The ground motions inside the basin (Seattle) were found to have larger spectral accelerations and more damaging spectral shapes.

• The collapse probability under an M9 CSZ earthquake were found to be mostly larger than MCE_R CS motions for both with and without basin effects considered.

• The 50-year collapse risk would likely exceed the 1% target in ASCE 7-16 if the simulated M9 CSZ motions in Seattle were considered.

References

Frankel, A., Wirth, E., Marafi, N. A., Vidale, J., & Stephenson, W. (2018). Broadband Synthetic Seismograms for Magnitude 9 Earthquakes on the Cascadia Megathrust Based on 3D Simulations and Stochastic Synthetics: Methodology and Overall Results. Bulletin of the Seismological Society of America. *Submitted for USGS review*

Marafi, N. A., Eberhard, M. O., Berman, J. W., Wirth, E.A., & Frankel, A. D. (2017). Effects of Deep Basins on Structural Collapse during Large Subduction Earthquakes. Earthquake Spectra, 33(3), 963-997. doi:10.1193/071916EQS114M

Zhou, Y., and Hueste, M. B. (2018). Review of Test Data for Interior Slab-Column Connections with Moment Transfer. ACI-fib International Symposium Punching Shear of Structural Slabs

This research was funded by the National Science Foundation under Grant No. EAR-1331412 and the funds provided by the Applied Technology Council for the ATC-123 report. The computations were facilitated through the use of advanced computational, storage, and networking infrastructure provided by the Hyak supercomputer system at the University of Washington. The authors also acknowledge the University of Texas at Austin and NSF Grant No. 1520817 (NHERI Cyberinfrastructure) for contributing to the research results reported within this poster. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the sponsoring agencies.

peer.berkeley.edu

USGS science for a changing world

Contact Information: Nasser Marafi, University of Washington, marafi@uw.edu