Design Strategies that Account for the Impacts of a M9 Earthquake on RC Wall Structures in Deep Sedimentary Basins

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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.

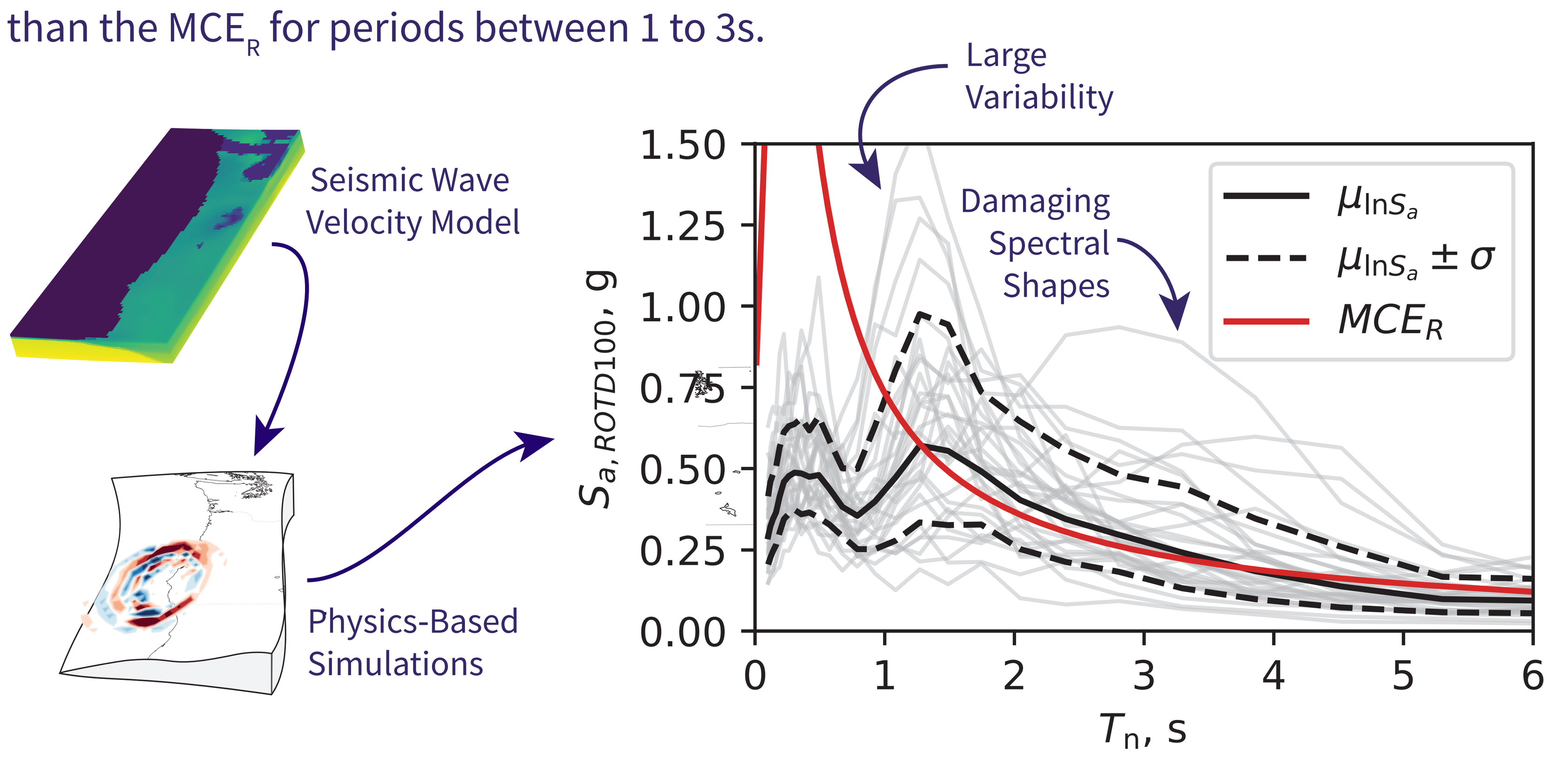
• The USGS estimates that an M9 CSZ earthquake has a 500-year return period with a 10-14% chance of occurance in the next 50 years.

• 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.

Physics-Based Simulations

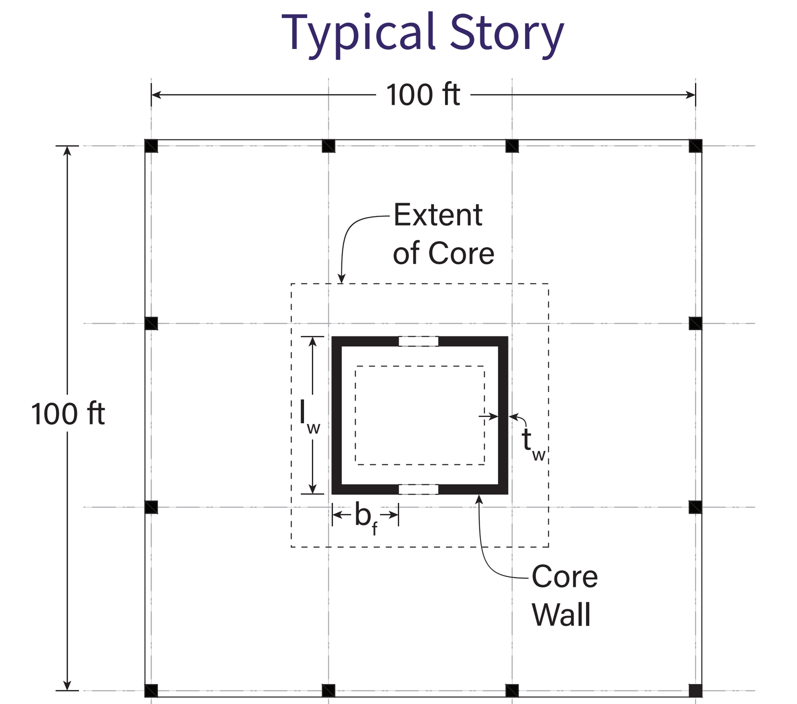
• Frankel et al. (2018) generated over thirty realizations of M9 CSZ scenarios which are largely based on the logic trees that make up the National Seismic Hazard Maps.

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



Archetype Development and Modeling

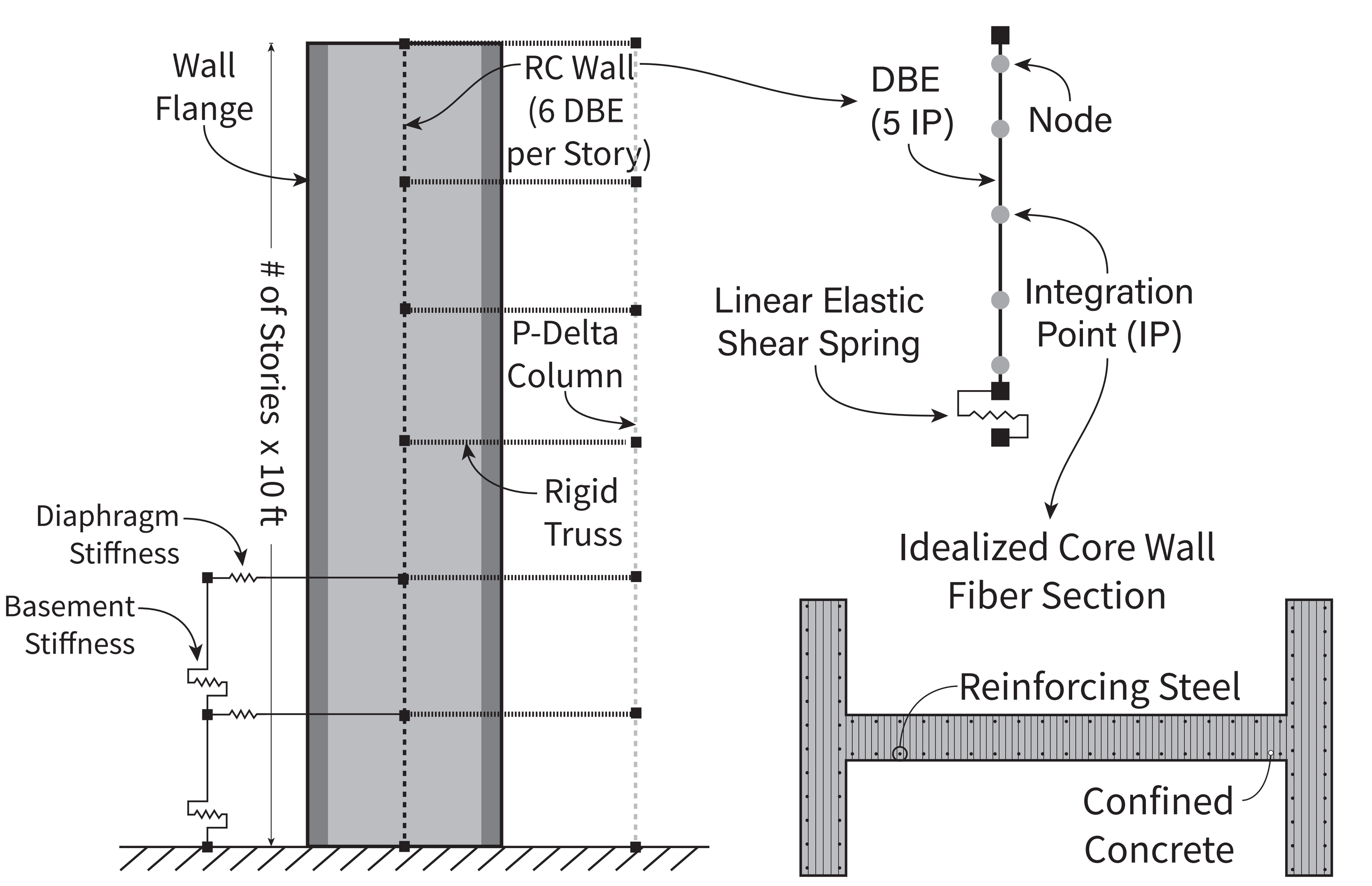
• The impacts of the M9 CSZ motions on building response were assesed using a suite of archetypes that were developed with engineering firms in Seattle through collaborative efforts with the Structural Engineers Association of Washington.



Site Properties
• Downtown Seattle
• Site V_{S30} = 500 m/s

Archetype Properties:
• ASCE 7-16
• R=6, I=1.0
• Modal Anaysis (MRSA)
• 4- to 24-stories
• 10' floor-to-floor height
• 2-4 basement Levels included
• 130 psf + Core Weight
• f_c = 8 ksi for core, 5 ksi elsewhere

• 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.



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.

Objectives

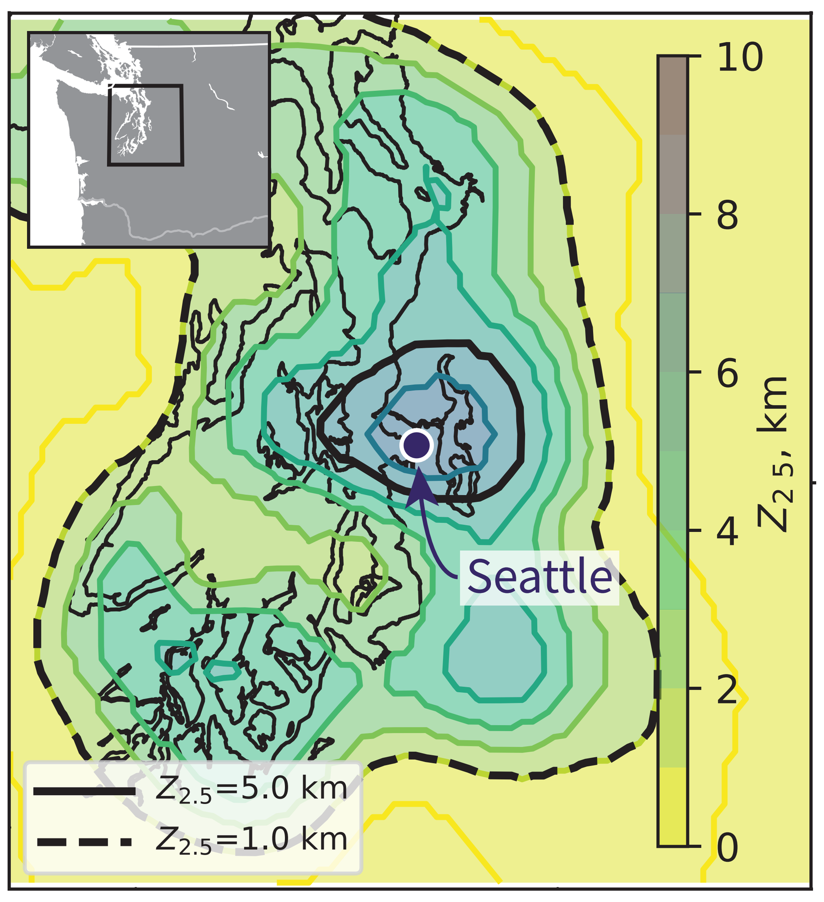
• Study the impact of an M9 CSZ earthquake on a suite of buildings in Seattle using (1) physics-based simulations and (2) nonlinear models of the structure's reponse.

• Assess design strategies that account for the impacts of a M9 CSZ Earthquake.

Deep Basins

• Buildings in Seattle are founded on glacially compacted till with a surface shear-wave velocity reaching up to 500 m/s

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

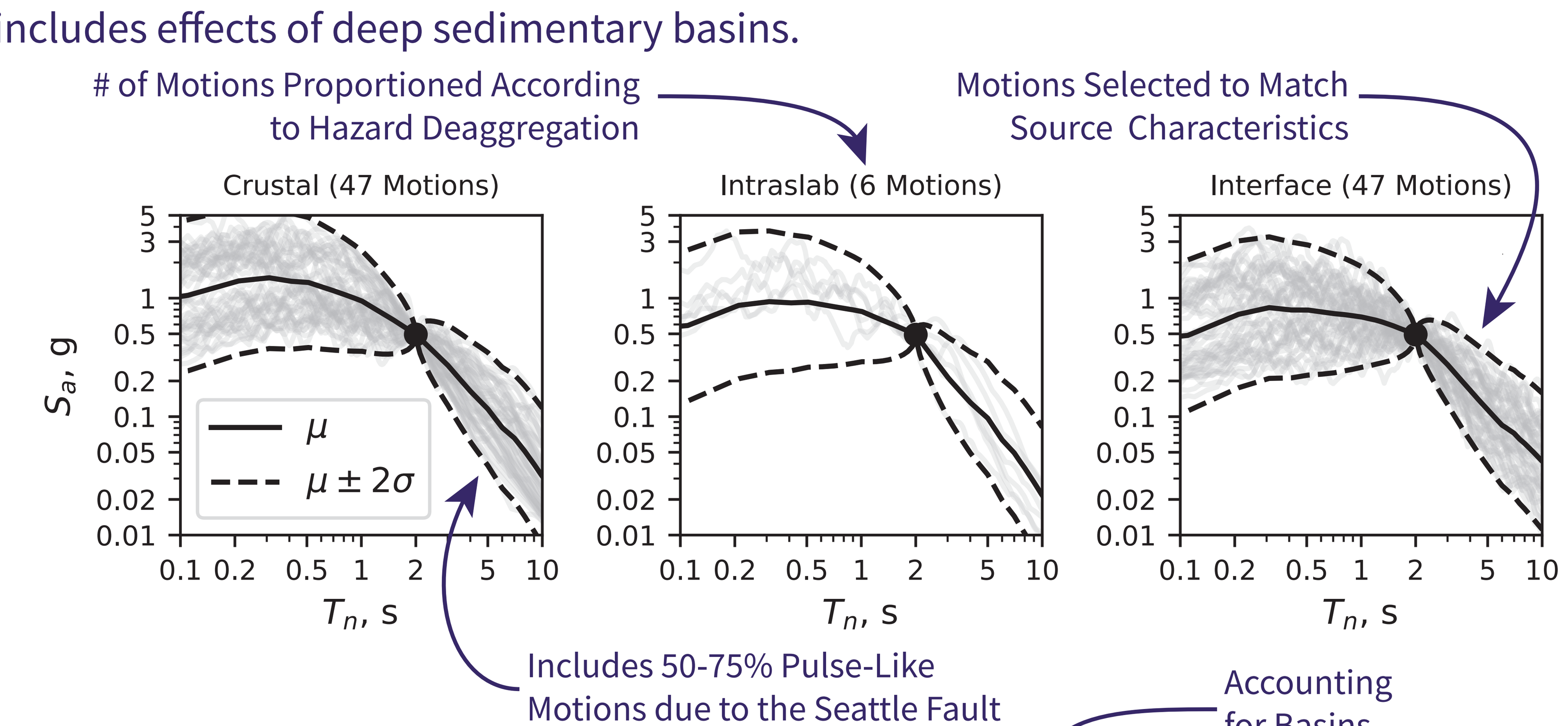


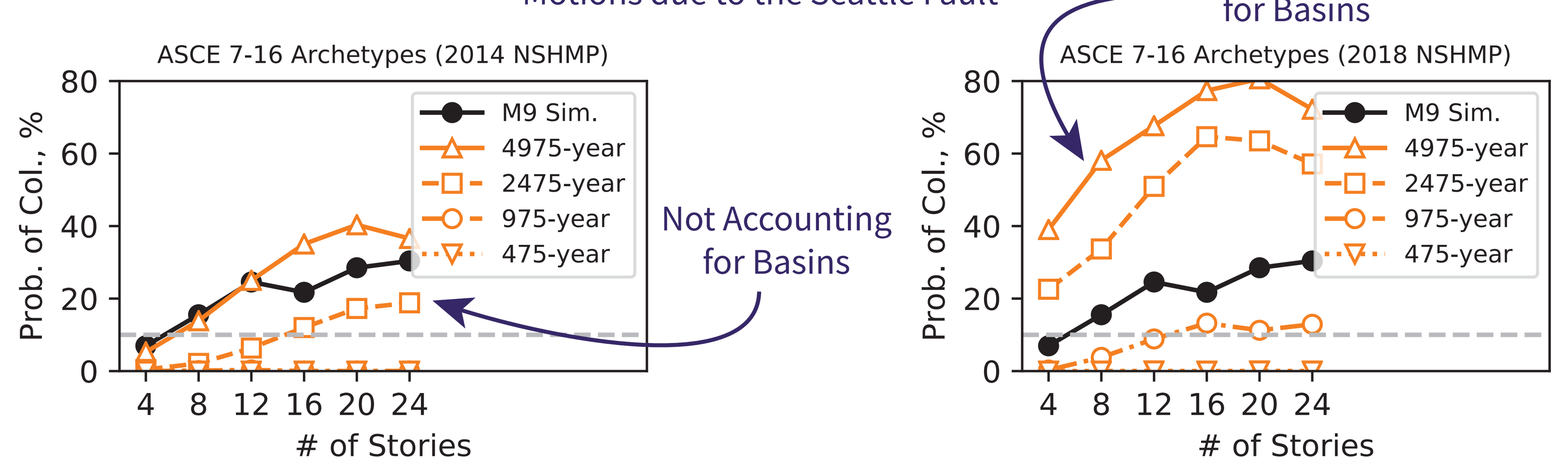
Multiple Stripe Analysis

• The performance of each archetype under an M9 CSZ earthquake is compared to ground-motions selected and scaled to match the conditional spectra at several intensity levels (earthquake return periods).

• The 2014 version of the NSHMP (referenced in ASCE 7-16) does not include effects of deep sedimentary basins.

• The 2018 version of the NSHMP (considerd for adobtion in the next ASCE 7) includes effects of deep sedimentary basins.

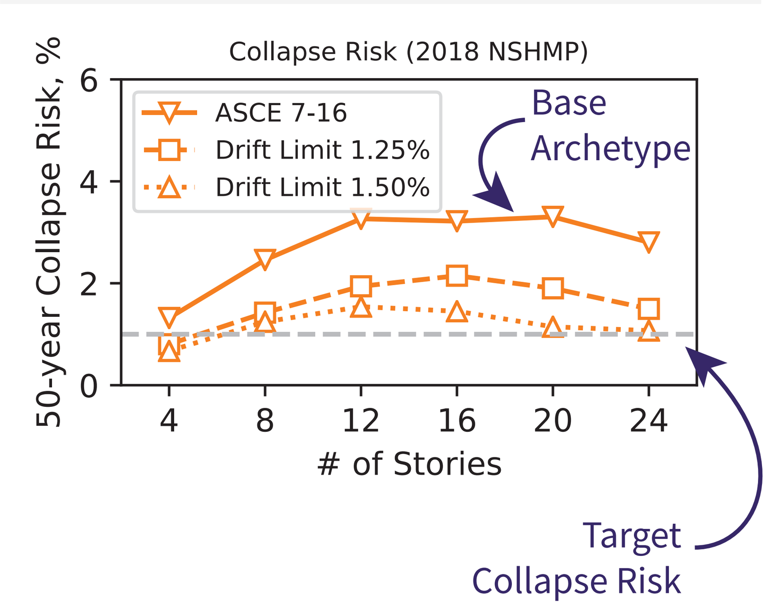




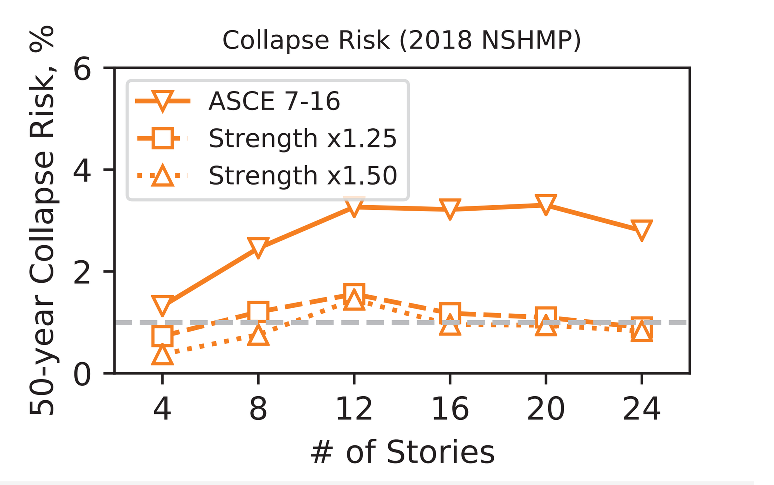
Design Strategies

• To account for deep basin effects and long durations of large magnitude earthquakes, the ASCE 7-16 archetypes have been redesigned to have a higher: (1) strength, (2) stiffness, and (3) gravity system drift capacity.

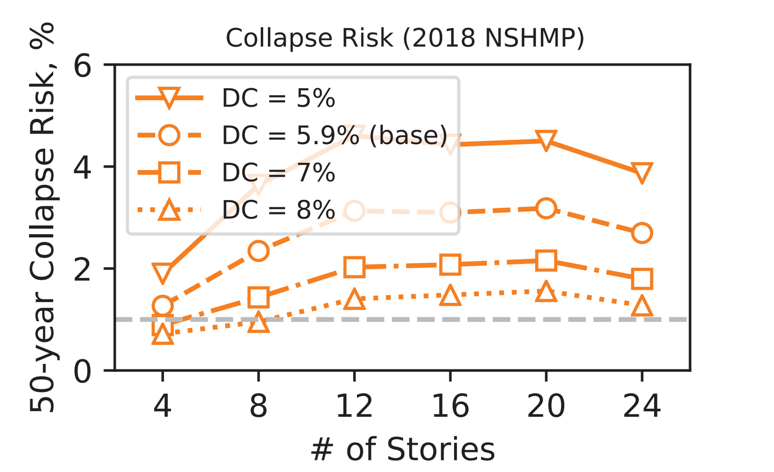
Increasing Stiffness



Increasing Strength



Increasing Gravity System Drift Capacity



Conclusions

• The ground motions inside the basin (Seattle) were found to have larger spectral accelerations and more damaging spectral shapes than the ASCE 7-16 MCE_R.

• The collapse likelihood under an M9 CSZ earthquake (500-year return) exceeded the collapse likelihood of a 2,475-year earthquake currently considered in the 2014 version of the National Seismic Hazard Map Project (used in ASCE 7-16).

• Accounting for basin effects in the NSHMP (2018) resulted in a 50-year collapse risk that exceeded the 1% target in 50-years.

• Increasing the structures's strength, stiffness, or gravity system drift capacity reduced the seismic collapse risk.

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