Influence of ground motion duration on structural collapse risk

Stanford University

Reagan Chandramohan, Jack W. Baker, and Gregory G. Deierlein

John A. Blume Earthquake Engineering Center, Stanford University

PEER

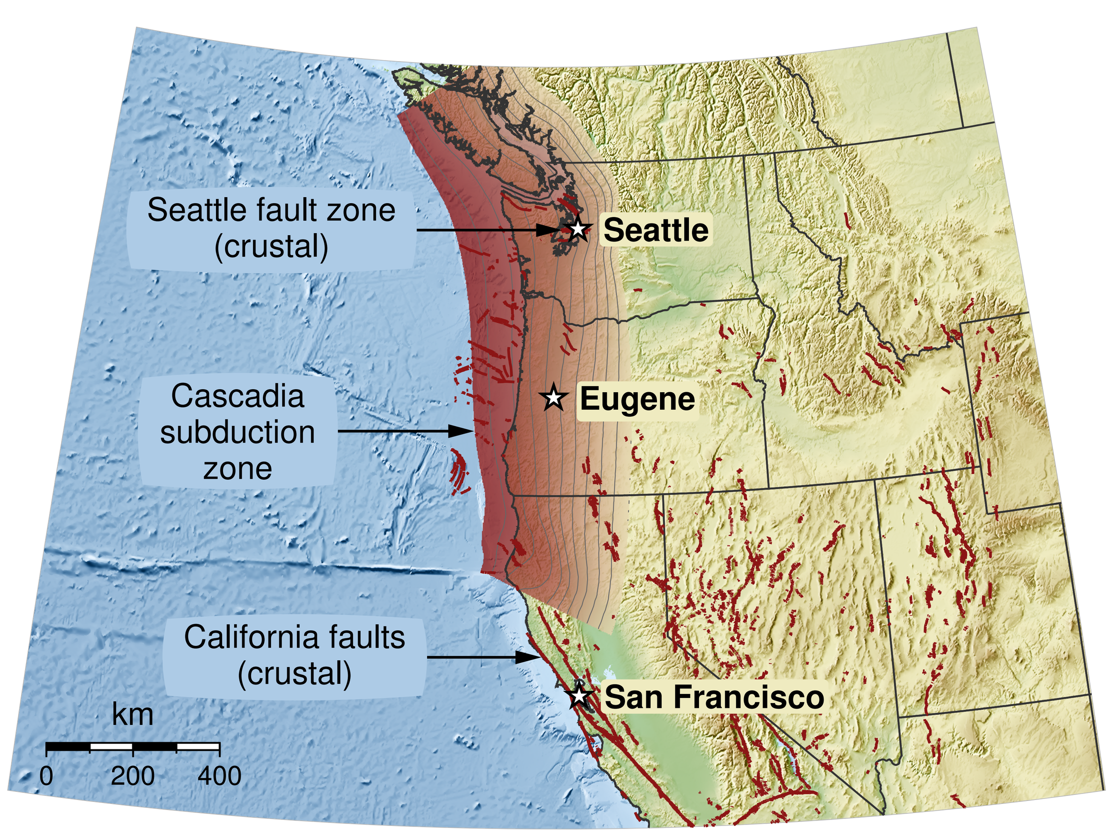
Background and Motivation

- In current seismic design and assessment practice, only the response spectra of the ground motions anticipated at a site are explicitly accounted for; not their durations
- Previous studies using spectrally equivalent long and short duration ground motions have demonstrated that ground motion duration does influence structural collapse capacity
- The effect of duration is attributed to the in-cycle and cyclic deterioration of structural strength and stiffness, and the ratcheting of drifts due to destabilizing $P-\Delta$ effects

Objectives

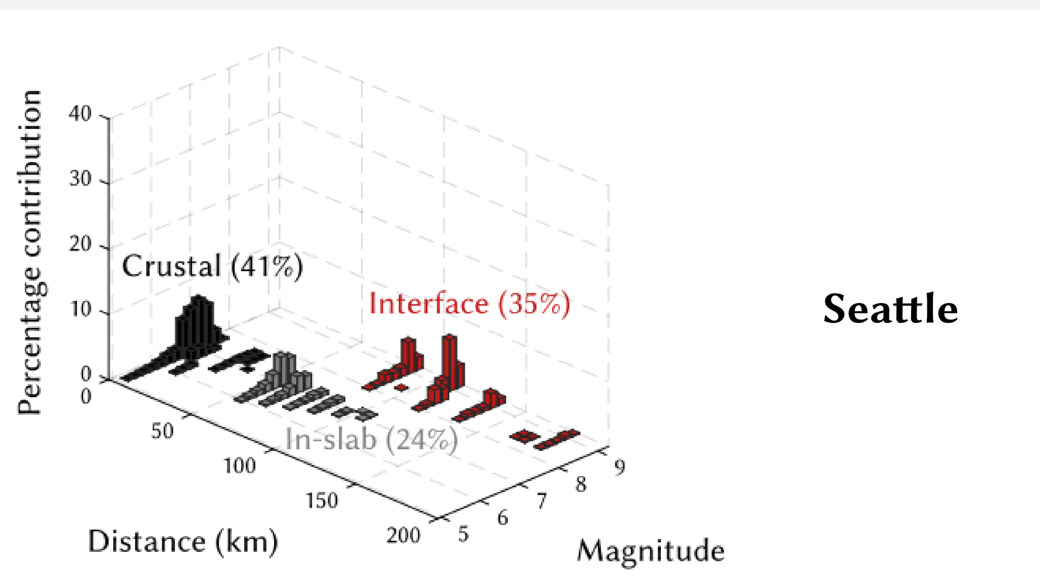
- Characterize seismic hazard in terms of the durations and response spectra of the anticipated ground motions
- Quantify the influence of ground motion duration on structural collapse risk at different sites
- Incorporate the effect of duration into structural design and performance assessment guidelines (*ongoing research*)

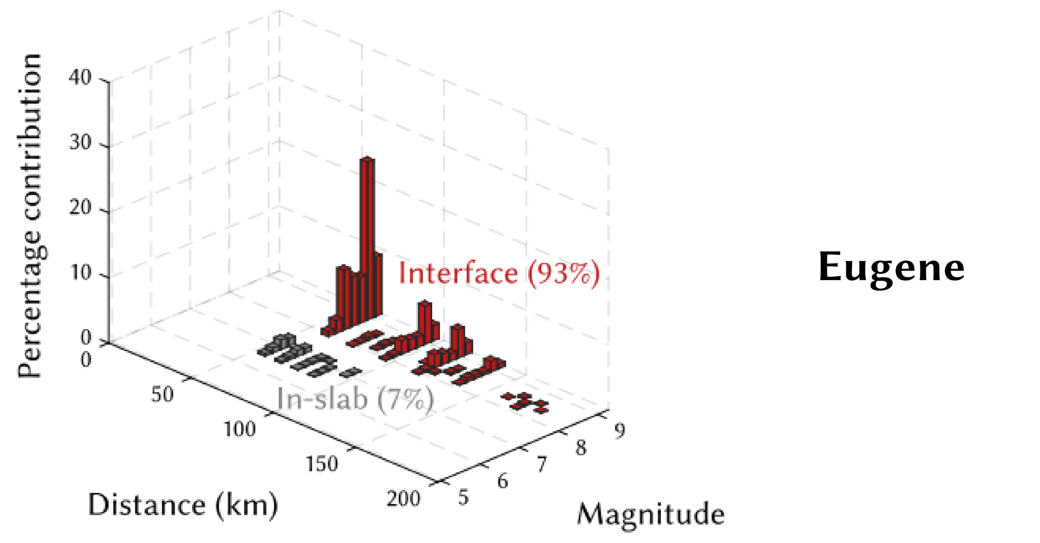
Chosen sites and seismic sources

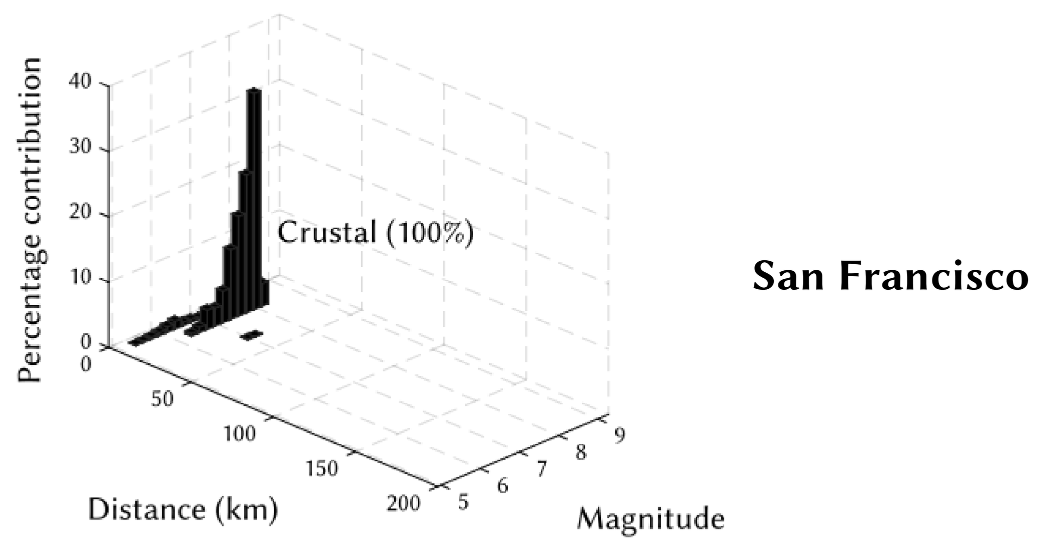


- The Cascadia subduction zone produces two types of earthquakes
  - Large magnitude *interface* earthquakes, e.g. 2011 Tohoku ($M_W = 9.0$)
  - Deep *in-slab* earthquakes, e.g. 2001 Nisqually ($M_W = 6.8$)

Seismic hazard deaggregation

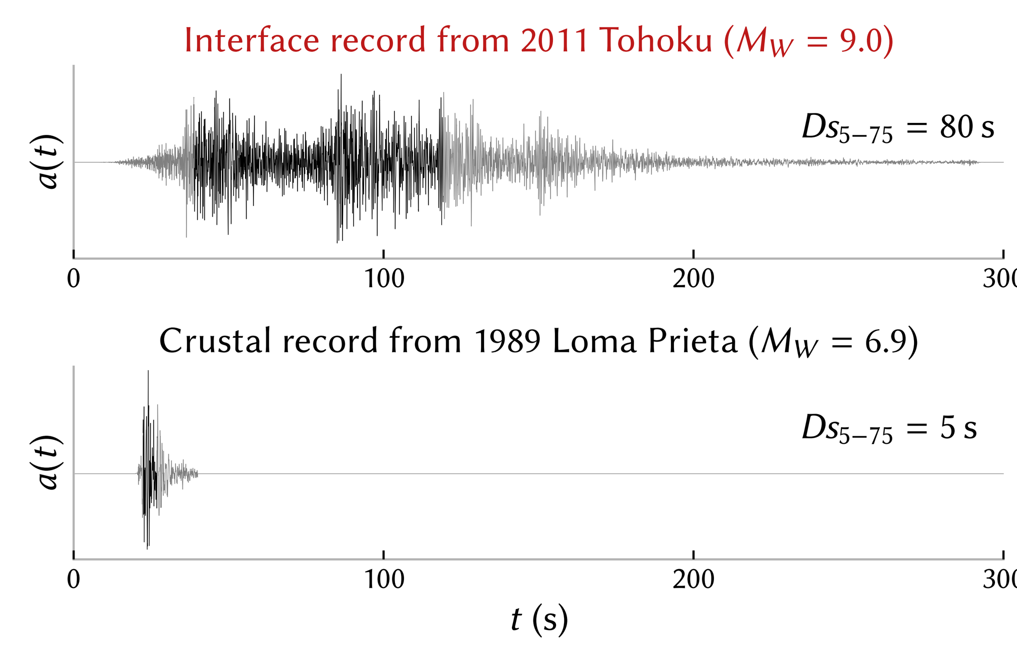




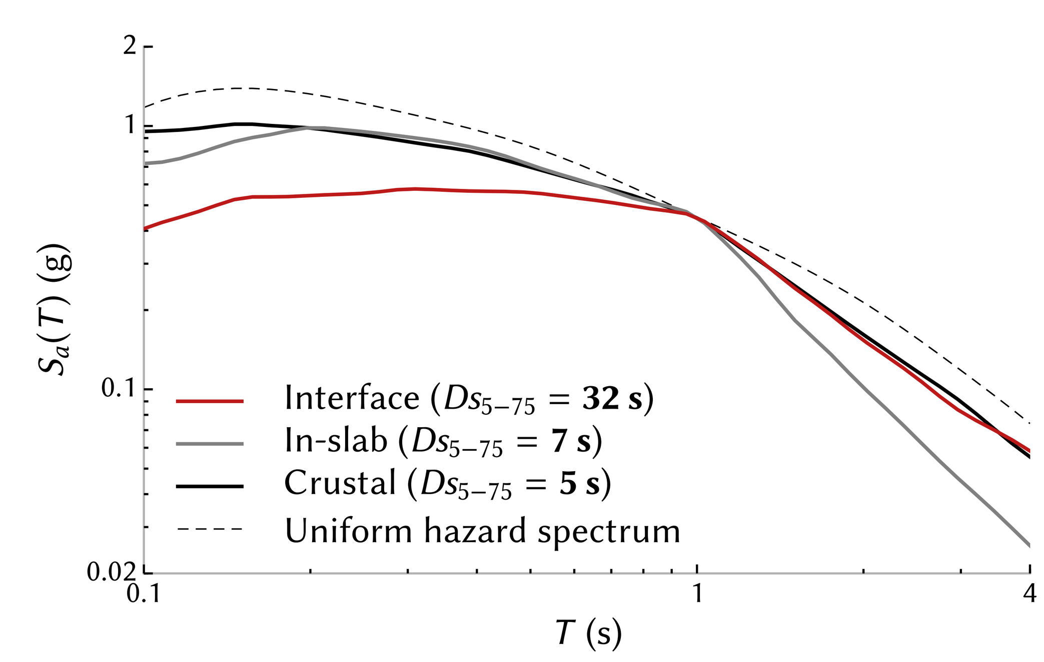


- Deaggregation results are conditional on the 2 % in 50 year exceedance probability of $S_a(1\,\text{s})$

Typical *interface* and *crustal* ground motions



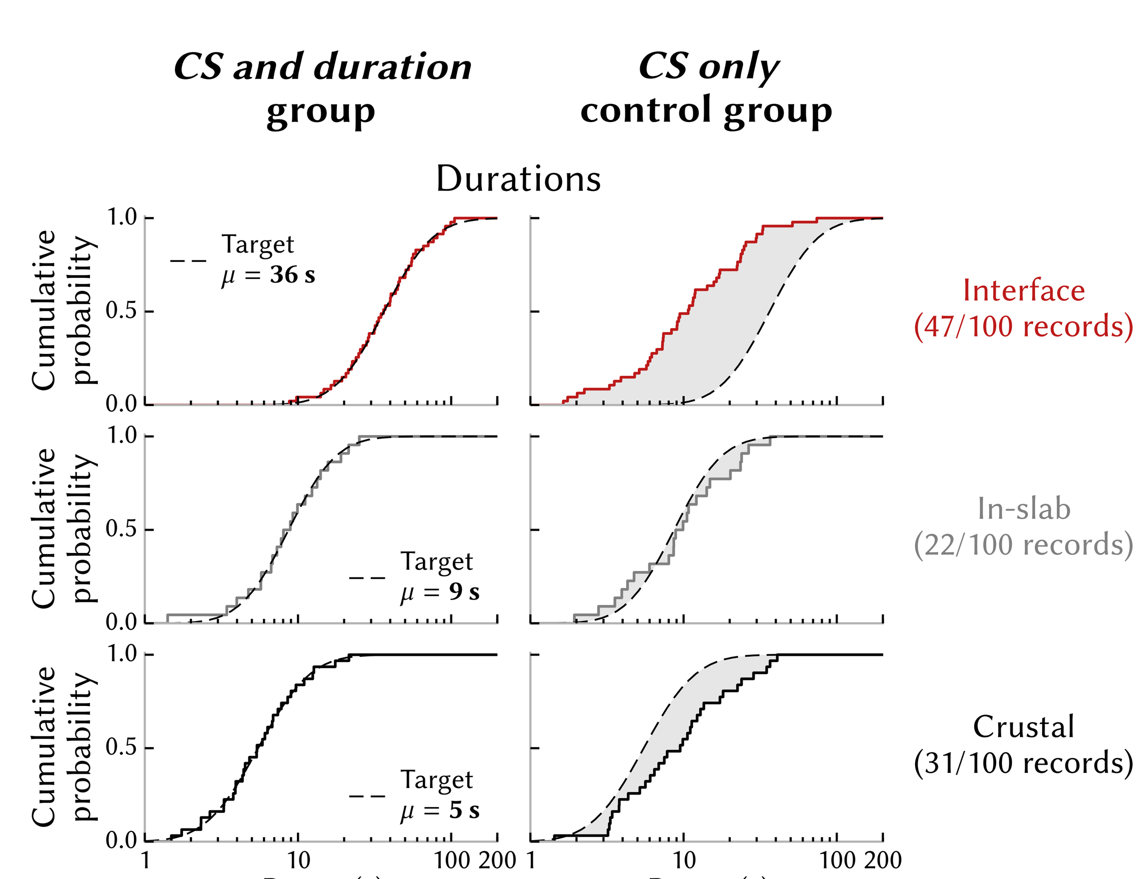
Median source-specific targets at Seattle

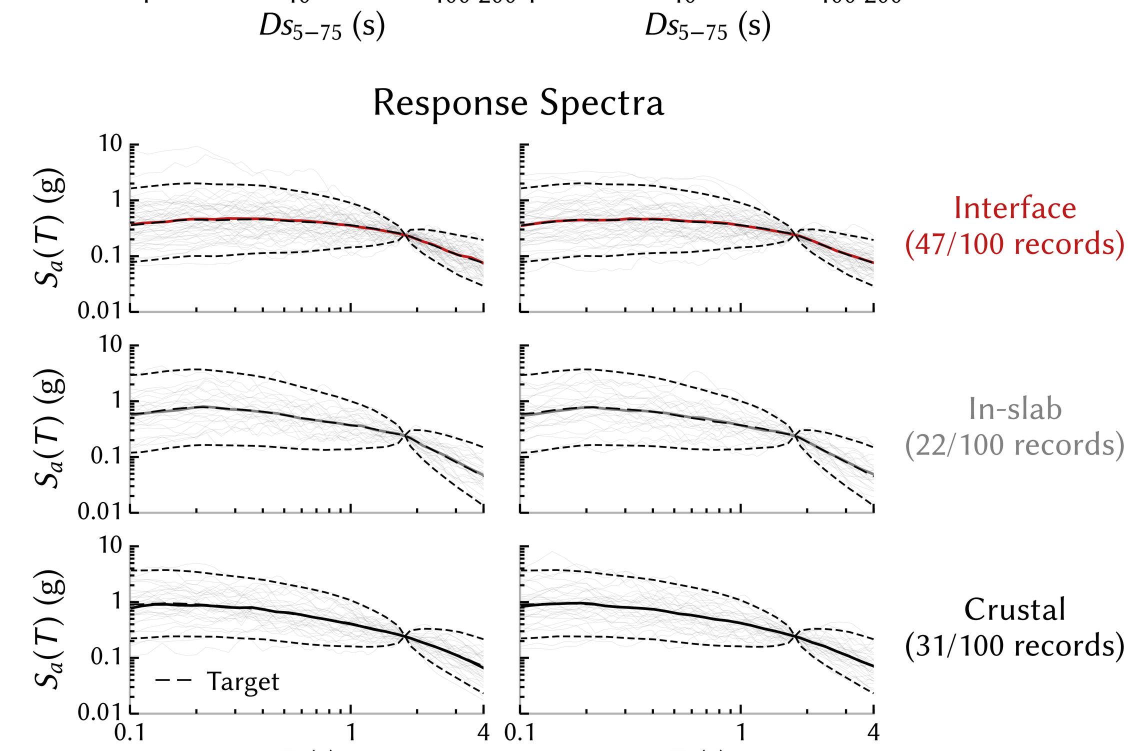


- Target distributions of 5-75% significant duration (Ds_{5-75}) are computed similar to a conditional spectrum using
  - deaggregation results
  - prediction equation for Ds_{5-75}
  - model for the correlation between the ε-values of Ds_{5-75} and $S_a(T^*)$

Ground motions selected for Seattle

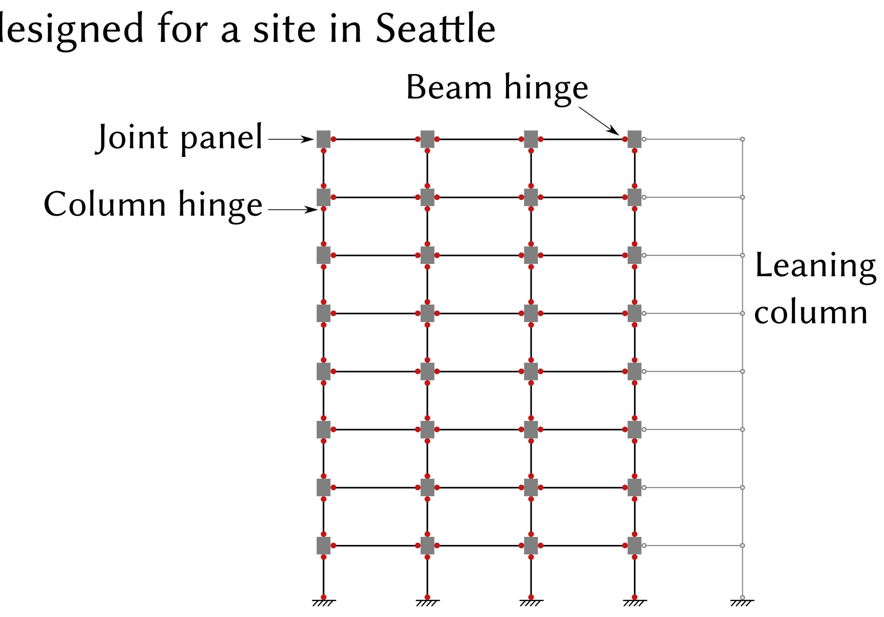
- *CS and duration* group
  - Selected to match duration and response spectrum targets
  - Interface records were selected from large magnitude earthquakes like 2011 Tohoku (Japan) and 2010 Maule (Chile)
  - In-slab and crustal records were selected from the PEER NGA database
- *CS only* control group
  - Selected to match response spectrum targets only
  - All records were selected from the PEER NGA database
- Each group contains 8 sets of records chosen at different intensity levels; each set contains 100 records



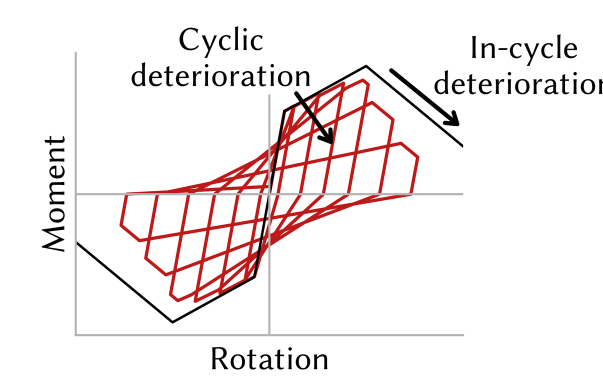


Structural model

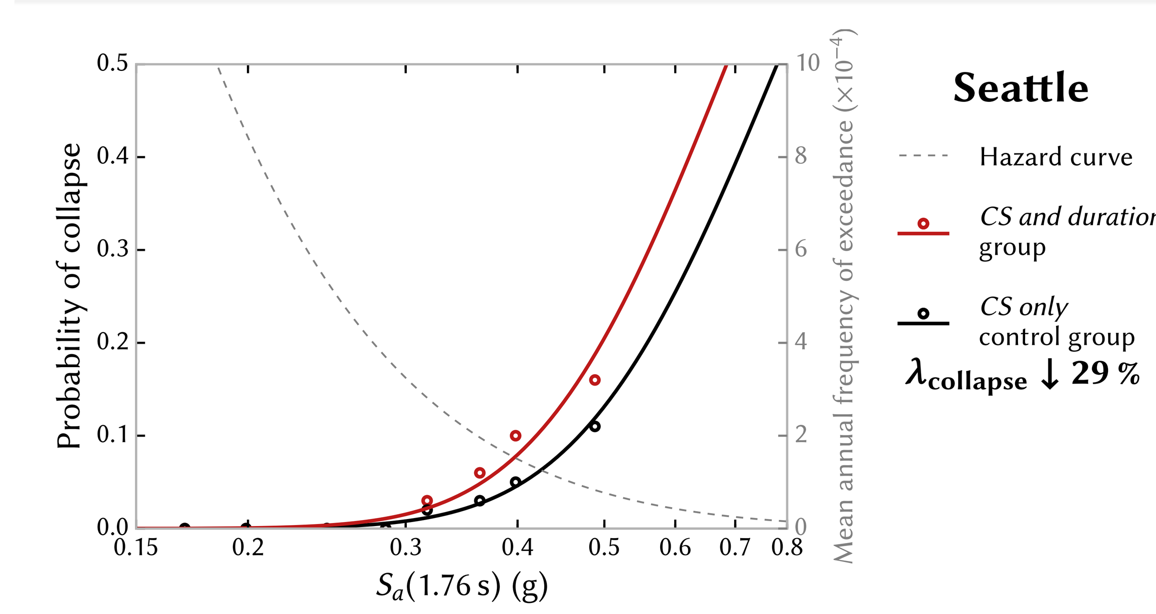
- Eight-story reinforced concrete moment frame building, designed for a site in Seattle



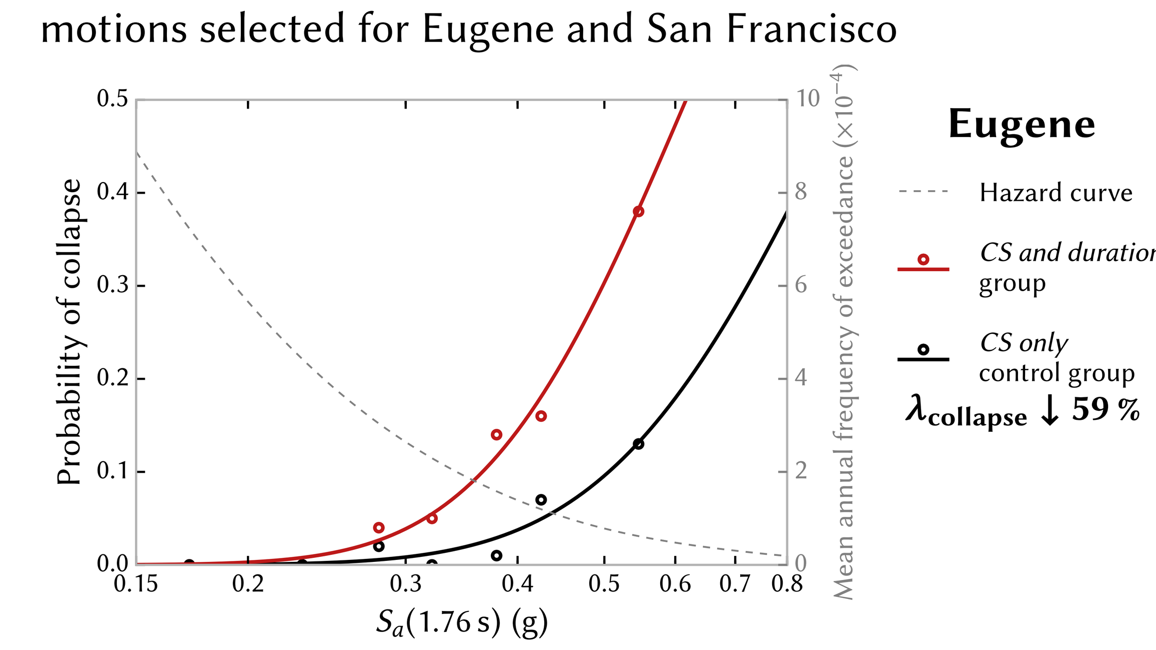
- Model accounts for the in-cycle and cyclic deterioration of strength and stiffness of the structural components, and destabilizing $P-\Delta$ effects

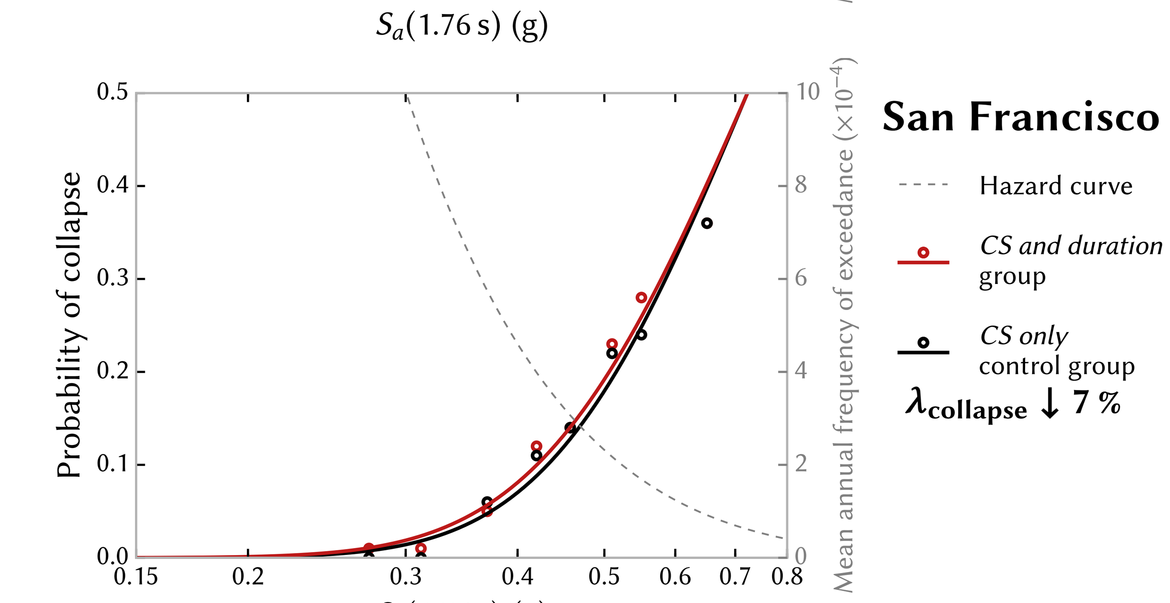


Collapse risk estimates



Structure was re-analyzed using different groups of ground motions selected for Eugene and San Francisco





Conclusions

- Selecting ground motions from the PEER NGA database without considering their durations can lead to the unconservative underestimation of structural collapse risk at sites where the seismic hazard is dominated by large magnitude ($M_W \sim 9.0$) interface earthquakes
- This warrants the explicit consideration of ground motion duration, in addition to response spectra, in structural design and performance assessment

Contact Information

Reagan Chandramohan

Email : reaganc@stanford.edu

Website : sites.google.com/site/reaganch