Influence of ground motion duration on structural collapse risk

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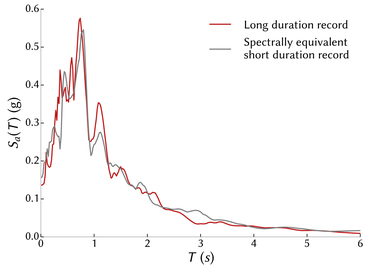
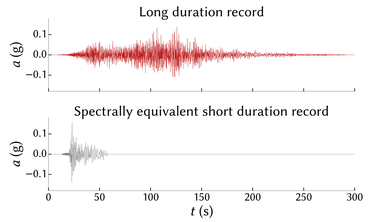
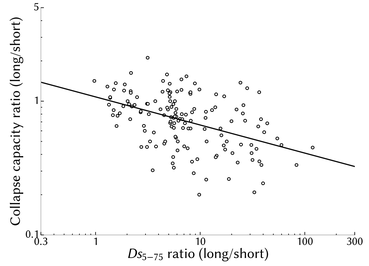
Background and Motivation

- Current structural design and assessment practice requires explicit consideration of only the response spectra of the ground motions anticipated at a site, not their durations
- In a previous study by the authors
  - 146 spectrally equivalent long and short duration record pairs were selected, with duration quantified using 5-75% significant duration (Ds_{5-75})





- Each ground motion was used to estimate a five-story steel moment frame's collapse capacity: the lowest $S_a(T_1)$ value it needs to be scaled to, to cause structural collapse

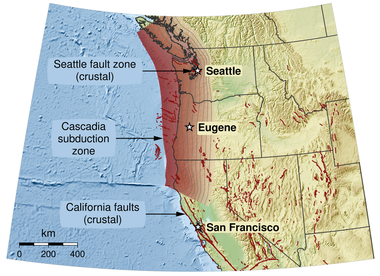


- Results help quantify the influence of ground motion duration on structural collapse capacity while controlling for the effect of response spectral shape

Objectives

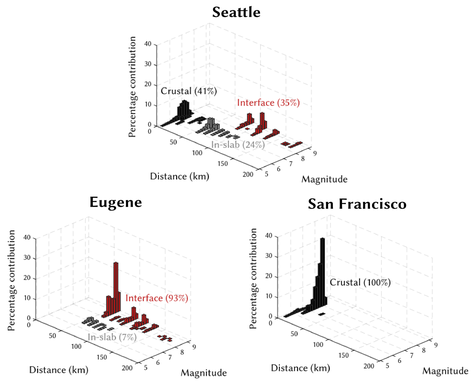
- Characterize seismic hazard in terms of the durations and response spectra of the anticipated ground motions
- Quantify the influence of ground motion duration on structural collapse risk at different sites
- Incorporate the effect of duration into structural design and performance assessment guidelines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

Chosen sites and surrounding seismic sources



- The Cascadia subduction zone produces large magnitude *interface* earthquakes and deep *in-slab* earthquakes

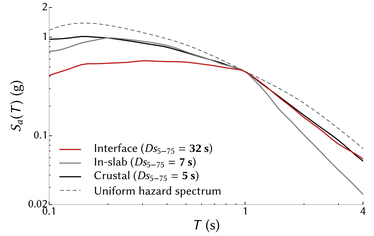
Seismic hazard deaggregation



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

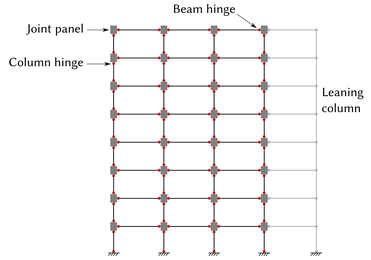
Hazard-consistent source-specific targets

- Target distributions of duration are computed using the GCIM, which is similar to a conditional spectrum, and requires
  - deaggregation results
  - a prediction equation for Ds_{5-75}
  - a model for the correlation between the ε-values of Ds_{5-75} and $S_a(T^*)$
- Median duration and response spectrum targets at Seattle, conditional on the 2% in 50 year exceedance probability of $S_a(1\,\mathrm{s})$

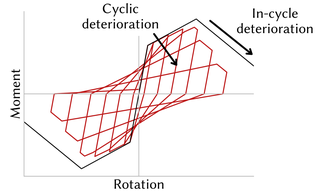


Structural model

- Eight-story reinforced concrete moment frame with fundamental period 1.76 s, designed for a site in Seattle

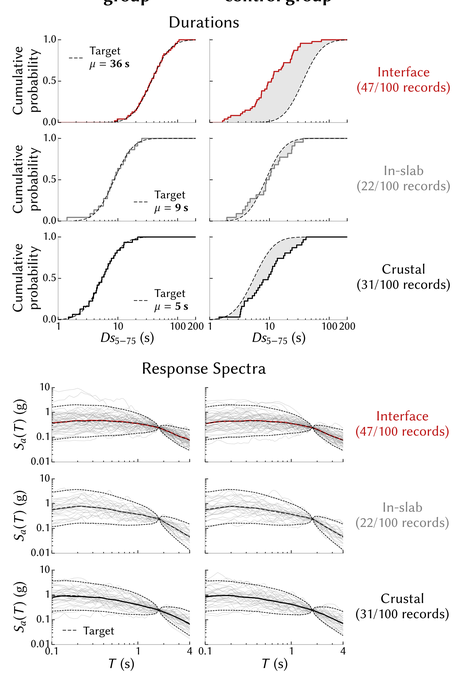


- Model incorporates the strength and stiffness deterioration of structural components and destabilizing $P-\Delta$ effects: both characteristics required to capture the effect of duration



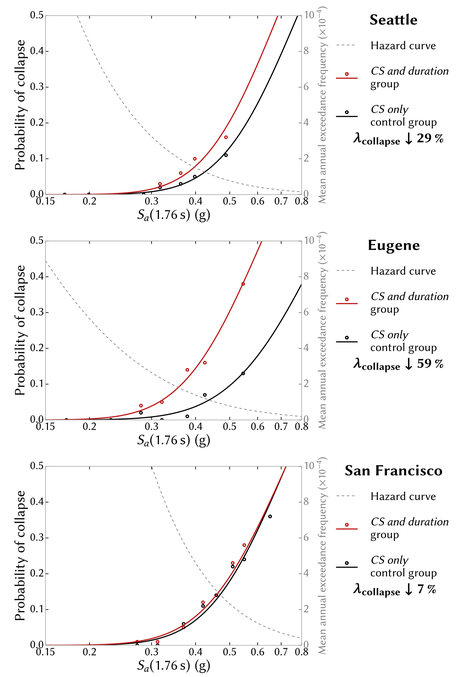
Selected ground motions

- Selected two groups of ground motions to match hazard at 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 (representative of current practice)
  - 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
- Seattle ground motions selected at 2% in 50 year hazard level



- Similar groups of records were chosen for Eugene and San Francisco

Collapse risk estimates



Conclusions

- Outlined a procedure to select hazard-consistent ground motions that match source-specific target distributions of duration and response spectra
- Highlighted the importance of considering ground motion duration, in addition to response spectra, in structural design and assessment
- Provided data that could help incorporate the effect of duration into seismic design codes, to ensure a uniform risk of structural collapse over different geographical regions

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