Influence of ground motion duration on structural collapse risk

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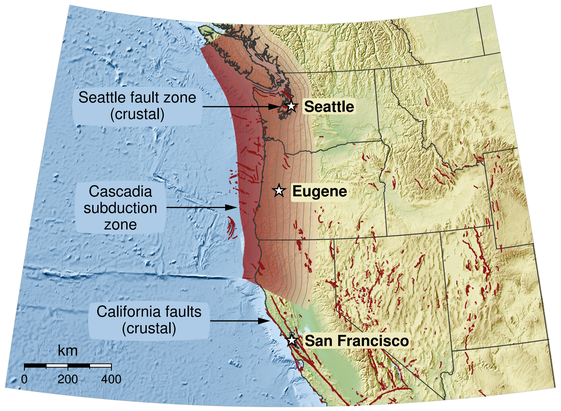
Background and Motivation

- Previous research has concluded that ground motion duration influences only cumulative damage metrics, not peak structural deformations
- 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
- Recent studies by the authors using spectrally equivalent long and short duration ground motions have demonstrated that duration does influence structural collapse capacity

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 in structural performance assessment and design standards

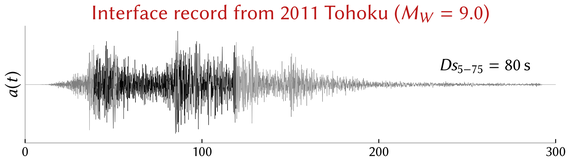
Chosen sites and surrounding seismic sources



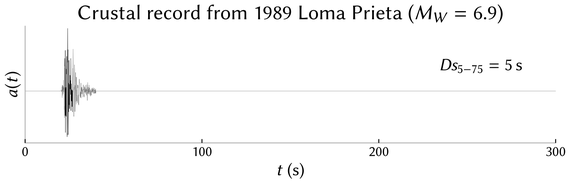
- The Cascadia subduction zone produces two types of earthquakes
  - Large magnitude *interface* earthquakes, e.g. 2011 Tohoku (M_W = 9.0)
  - Deep *in-slab* earthquakes, e.g. 2001 Nisqually (M_W = 6.8)

Typical *interface* and *crustal* ground motions

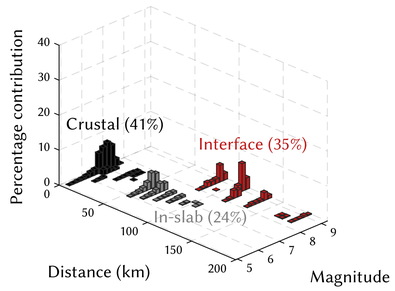
Interface record from 2011 Tohoku (M_W = 9.0)



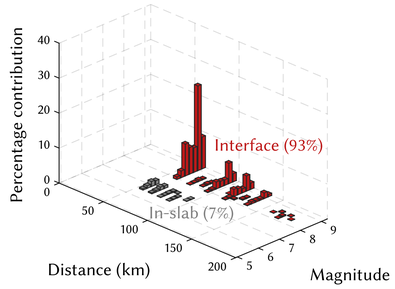
Crustal record from 1989 Loma Prieta (M_W = 6.9)



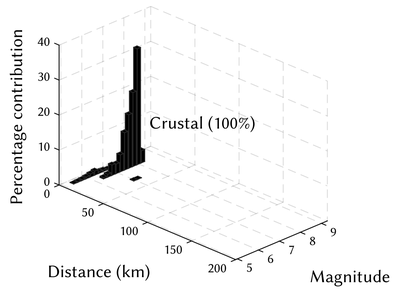
Seismic hazard deaggregation



Seattle



Eugene

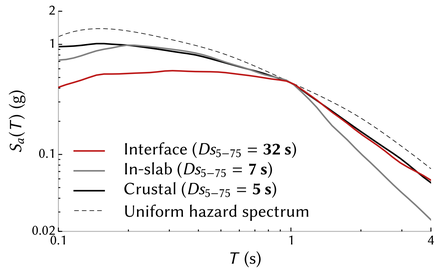


San Francisco

- Deaggregation results are conditional on the 2 % in 50 year exceedance probability of S_a(1 s)

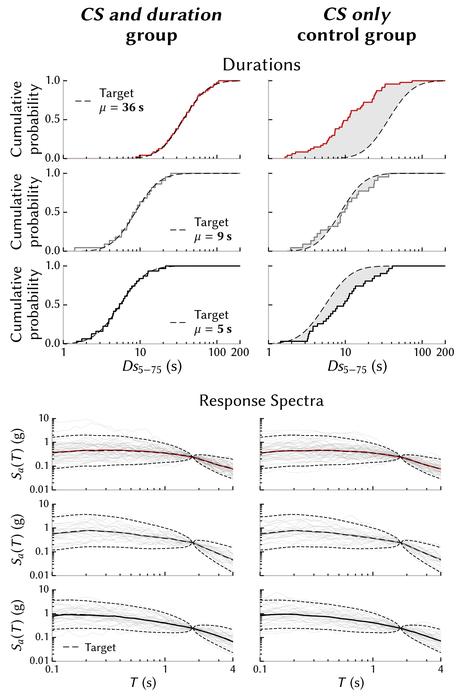
Hazard-consistent source-specific targets

- Target distributions of duration are computed using the GCIM, which is similar to a conditional spectrum, and requires
  - deaggregation results
  - prediction equation for Ds_{5-75}
  - 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 s)



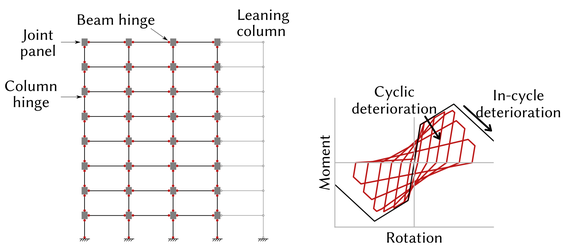
Selected ground motions

- 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
  - 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 % at 50 year hazard level

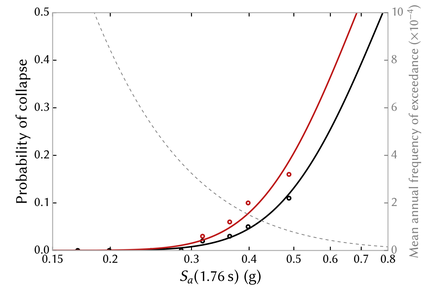


Structural model

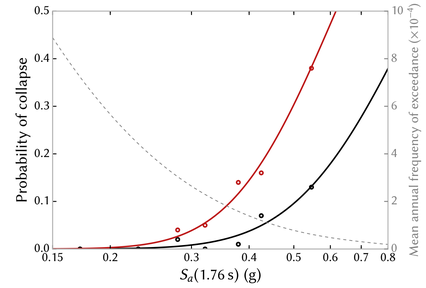
- Eight-story reinforced concrete moment frame building with a fundamental period 1.76 s, designed for a site in Seattle
- Model incorporates the strength and stiffness deterioration of structural components and destabilizing $P-\Delta$ effects: both characteristics required to capture the effect of duration

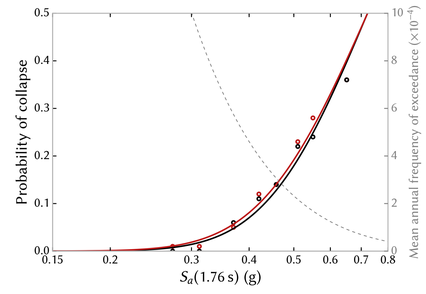


Collapse risk estimates



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





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 explicitly considering ground motion duration, in addition to response spectra, in structural performance assessment and design
- Developed a basis to incorporate the effect of duration in seismic design codes, to ensure a uniform risk of structural collapse over different geographical regions

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