Evaluation of the angle of seismic incidence effect on the collapse risk of RC buildings

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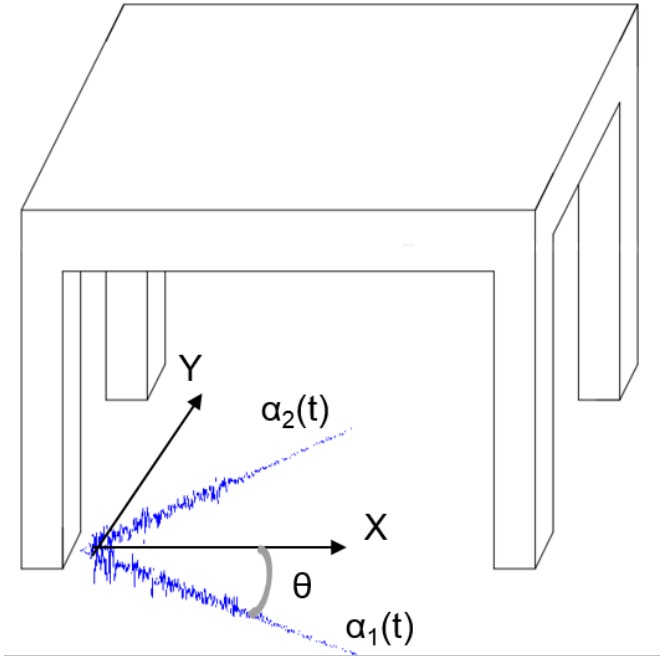
The angle of incidence of the seismic input

What is the angle of seismic incidence?

How do we account for it?



Traditionally one angle:

θ = 0° and $\alpha_1(t)$ // X, $\alpha_2(t)$ // Y

However, is it adequate??

Angle of seismic incidence (ASI) {θ}

Some outcomes of the research

Effect of the ASI and GM group size on the collapse risk:

- The ASI has negligible effect on the collapse risk **variation**. Using only 1 ASI introduces up to 10% bias in the median collapse risk, regardless of the GM group size.
- The GM group size has a significant effect on the variability of the collapse risk. A minimum number of 20 GM is suggested.
- Using 2 ASIs (0° and 90°) is enough to correct the bias in most of the cases, while 4 ASIs is a safe choice.

Scope and research methodology

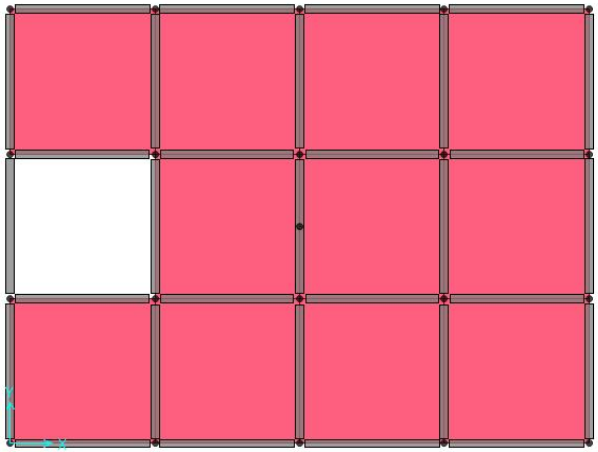
Scope: Comparison of the collapse risk obtained with a large number of ASIs and GMs with the collapse risk obtained with a reduced number of ASIs and GMs.

How:

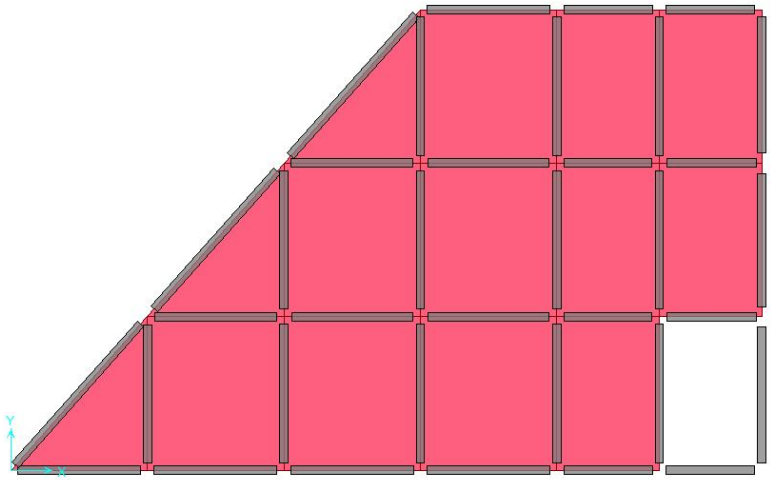
- Analysis of six 3D RC structures (regular and irregular in-plan, different number of storeys), located at a benchmark site.
- Nonlinear time history analysis with reference group of 40 GMs applied along 12 ASIs.
- Reduced sizes of GMs: 10, 15 ,20, 25, 30, 35.
- Reduced number of ASIs: 1 to 11.
- Examine the effect of the reduced information, induce by the number of ASIs and GMs, on the collapse risk..

Structures analysed: Layout

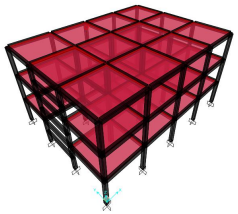
Regular



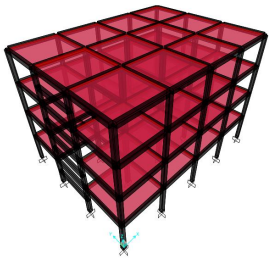
Irregular



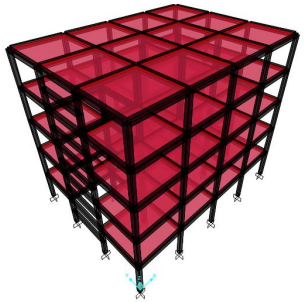
3 storeys



4 storeys



5 storeys

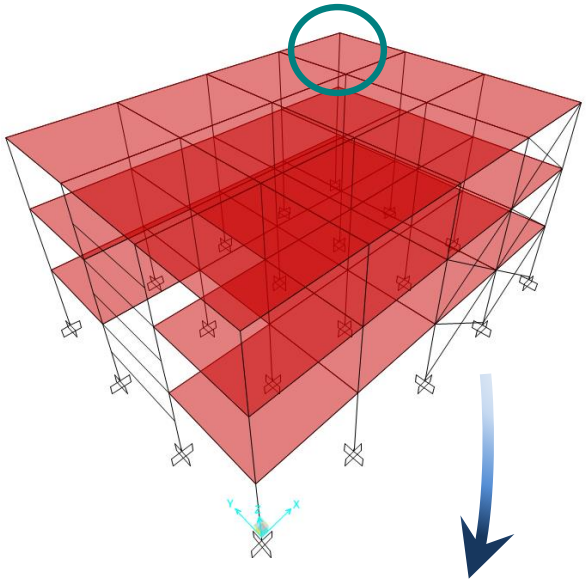


3 storeys

4 storeys

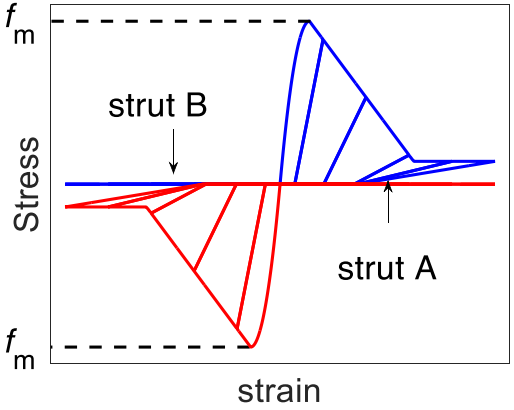
5 storeys

Structures analysed: Modelling



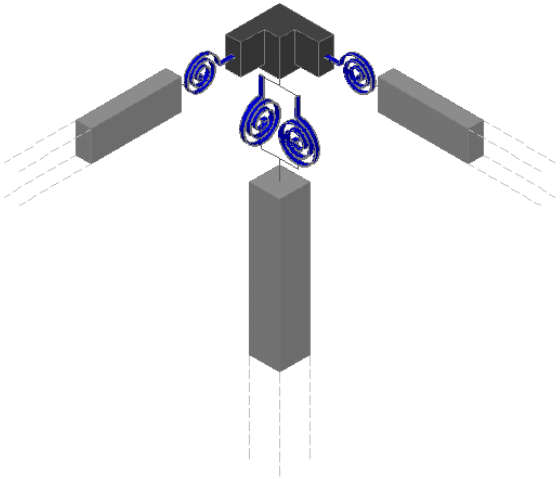
Full/partial infills in peripheral frames

2 struts/infill (compression-only)



Backbone Curve of infill w/wo opening. Dolsek and Fajfar (2008), Panagiotakos and Fardis (1996)

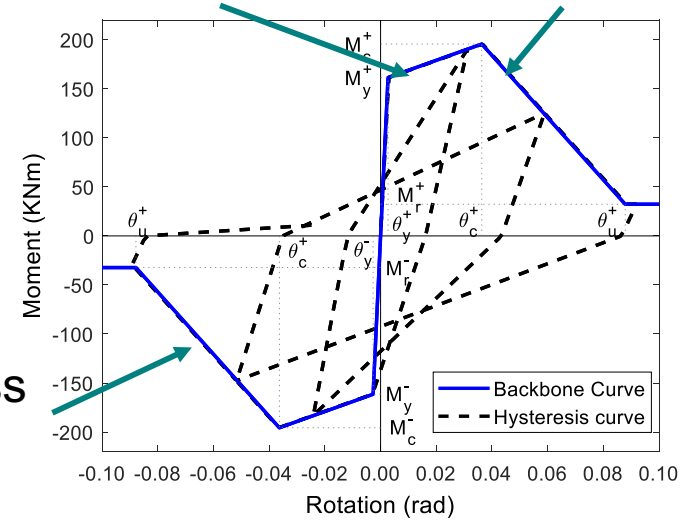
Lumped plasticity model



Stiffness degradation

Strength degradation

Unloading stiffness degradation

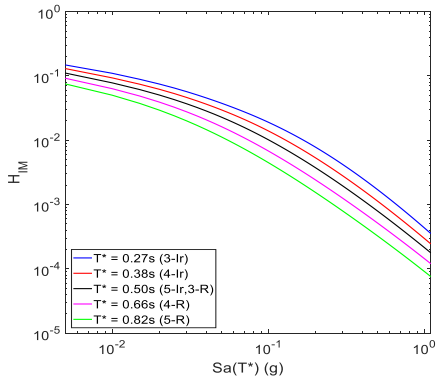


Hysteresis loop. Panagiotakos and Fardis (ACI 2001), Ibarra, L. F., and Krawinkler, H. (2005), Haselton, et al (2008)

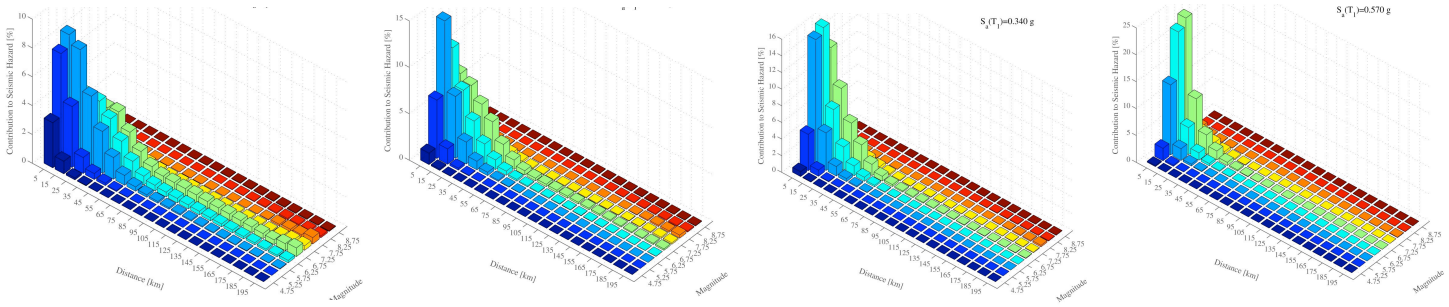
Ground motion selection

Location Lisbon, Portugal

a) PSHA

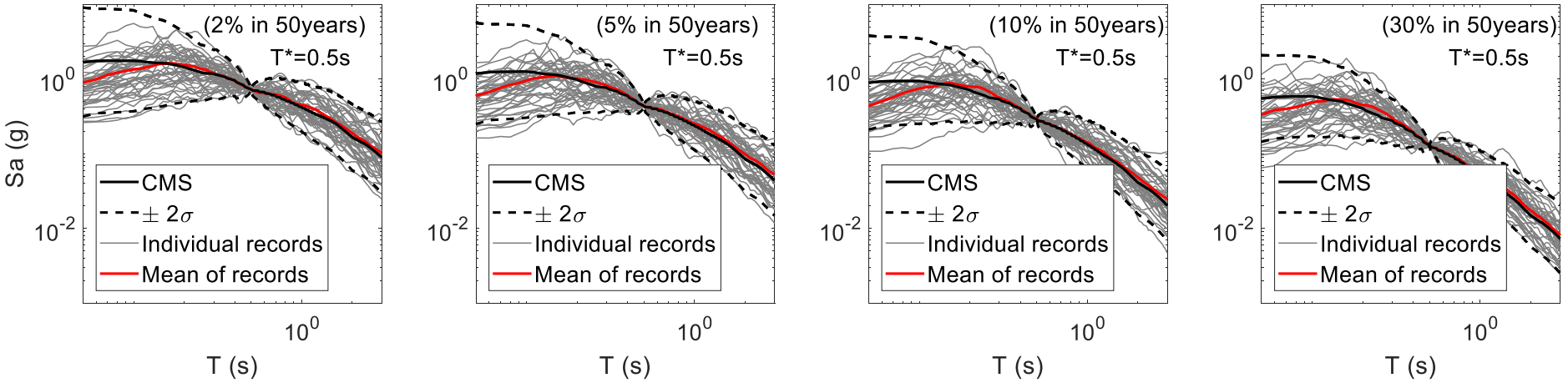


b) Hazard disaggregation for 4 probabilities of exceedance



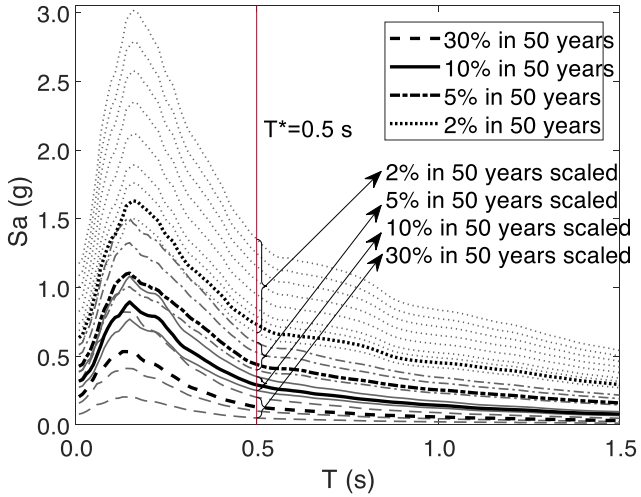
30% in 50 years | 10% in 50 years | 5% in 50 years | 2% in 50 years

c) CMS (Baker JW (2010)) 40 pairs of GMs



Probabilistic demand model

Multiple-stripe analysis 21 intensities (Jalayer & Cornell 2009)



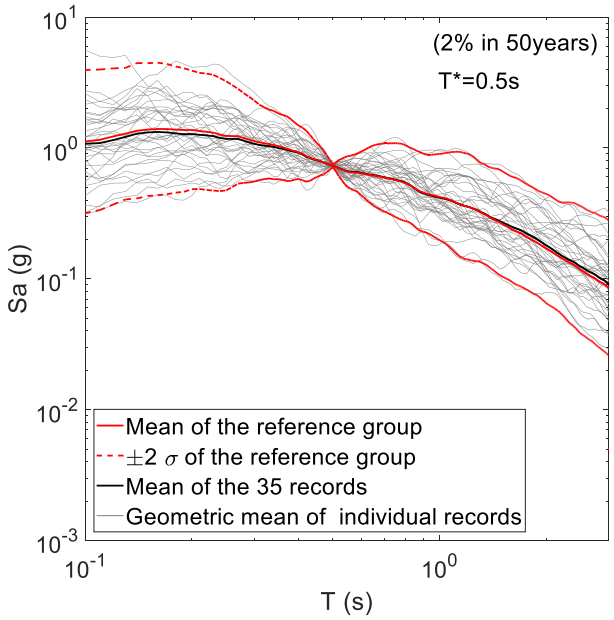
- 40 GM pairs compatible with CMS
- 12 ASIs [0° 165 °] steps of 5 °
- 21 intensities
- 6 buildings

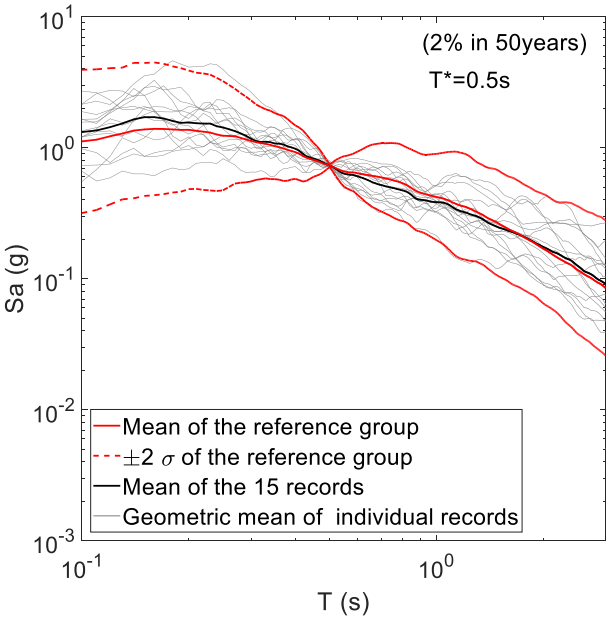
60.480 NLTHA

60.480 (analyses) × 15 (mins) = 907200 mins ~ 1.7 years (with a single core)

Ground motion regrouping procedure

- Each GM group of size 40 is regrouped into GM groups of size: 10, 15 ,20, 25, 30 and 35.
- Regrouping criteria consistent with the initial selection to ensure compatibility with the seismic scenario.
- Total number of 100 groups are created for each combination of a certain GM group size and number of ASIs (1-12).





Collapse risk modeling and uncertainty considerations

Capacity modelling:

- Ultimate chord rotation in a column
- Shear failure in a column
- Numerical failure of the model

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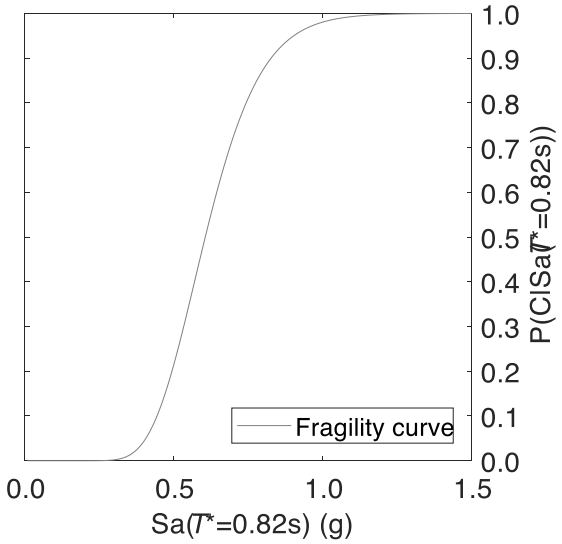
Fragility curve $\mathrm{P}\left(\mathrm{C}|\mathrm{IM}=x\right)$

1 group of a given combination: GM group size & ASI



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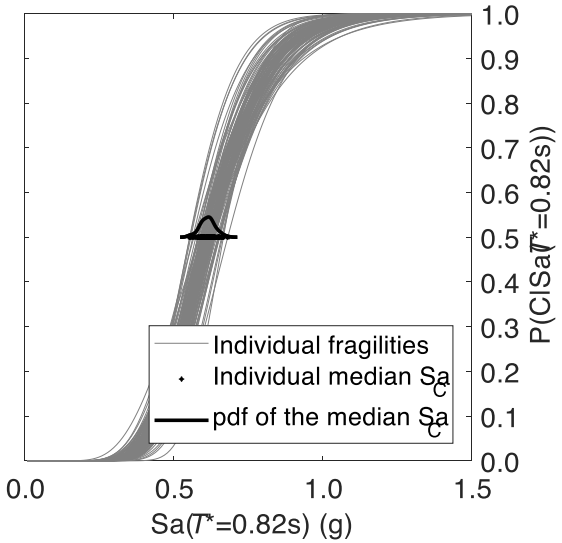
100 groups of a given combination: GM group size & ASI



Collapse risk modeling and uncertainty considerations

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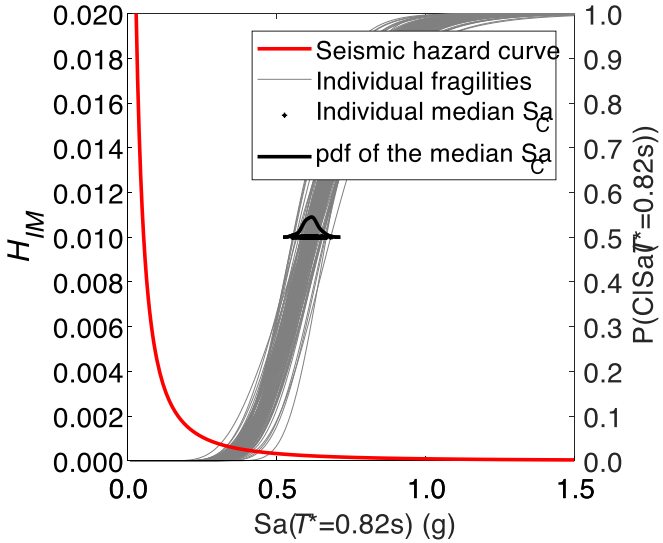
Rate of collapse (risk)

$$\lambda_C = \int_0^\infty \mathrm{P}\left(\mathrm{C}|\mathrm{IM} = x\right) dH_{\mathrm{IM}}(x)$$



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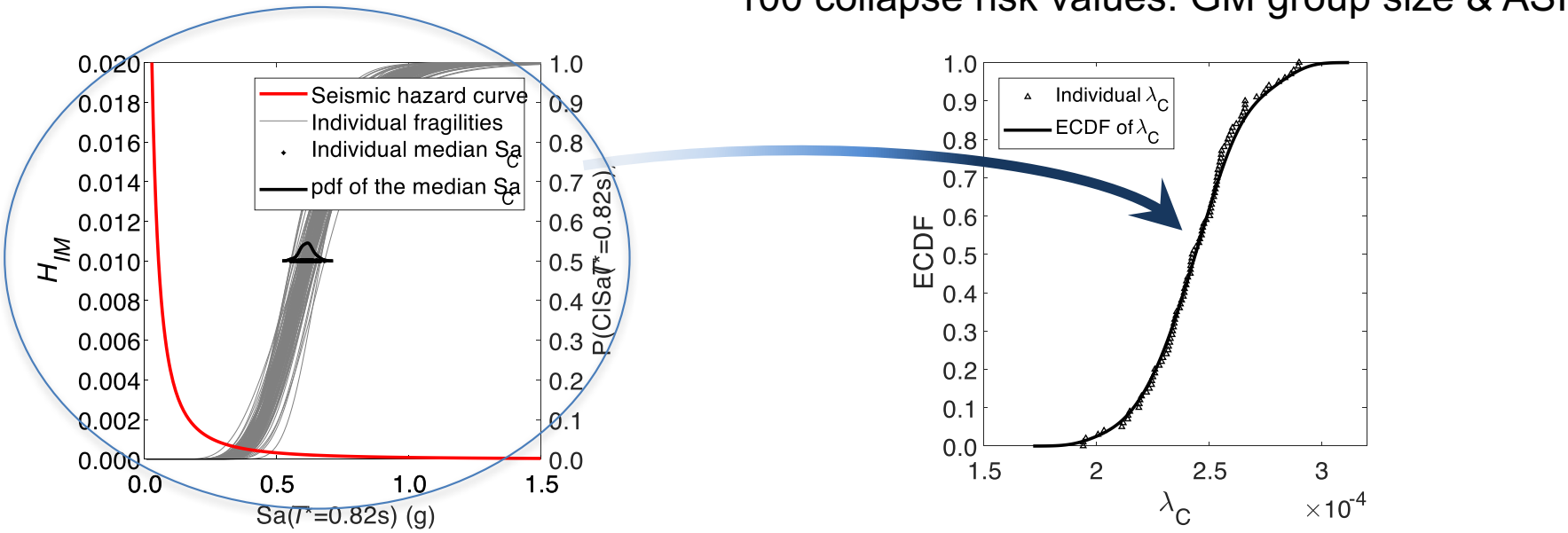
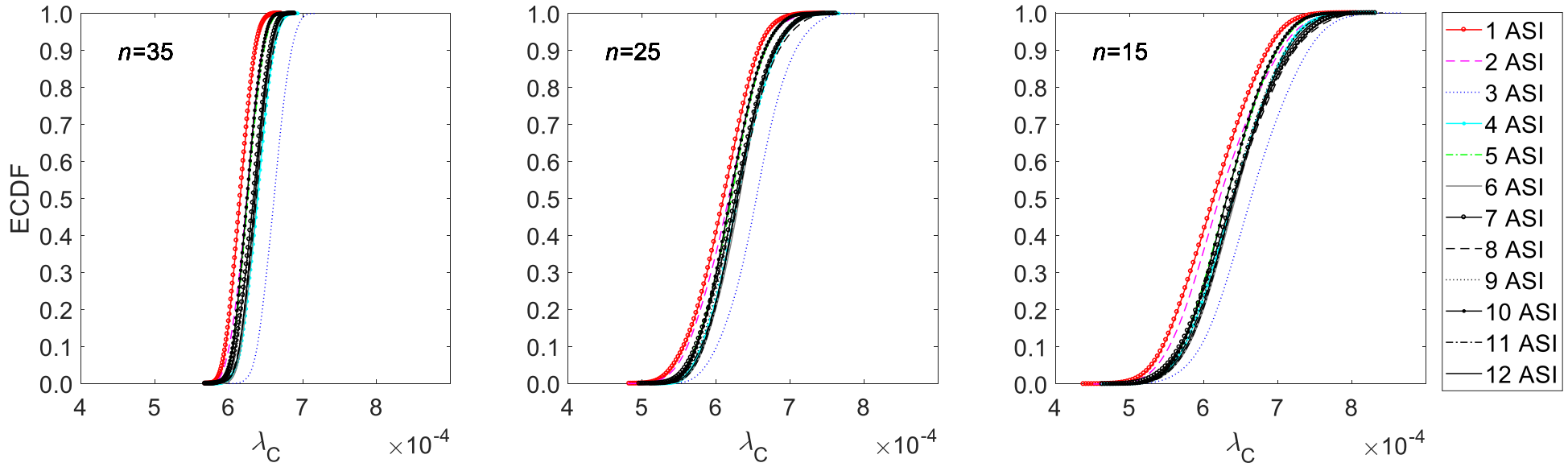
100 collapse risk values: GM group size & ASI

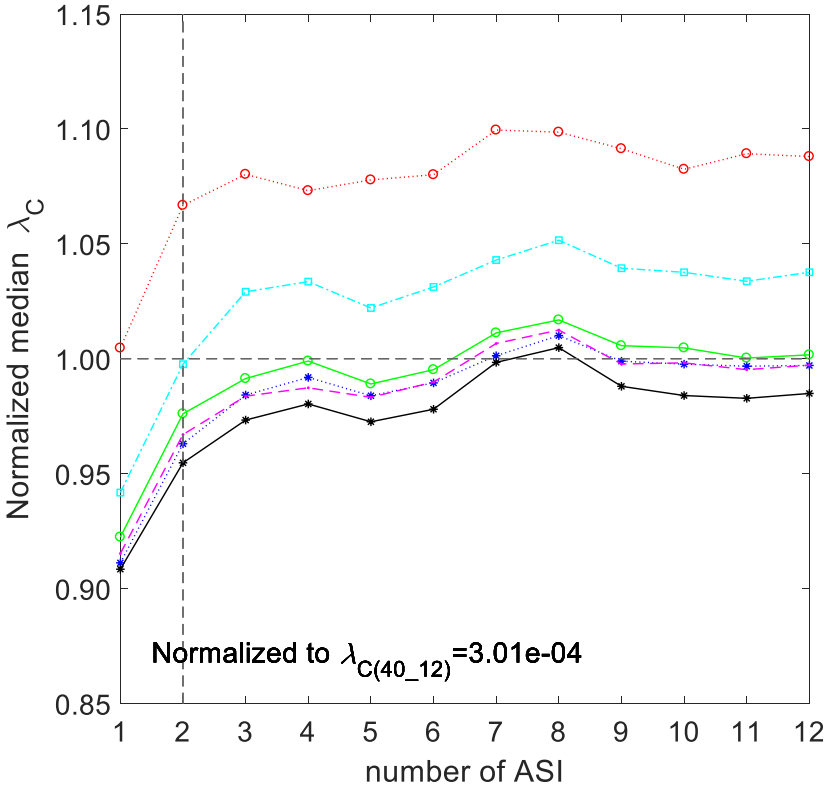


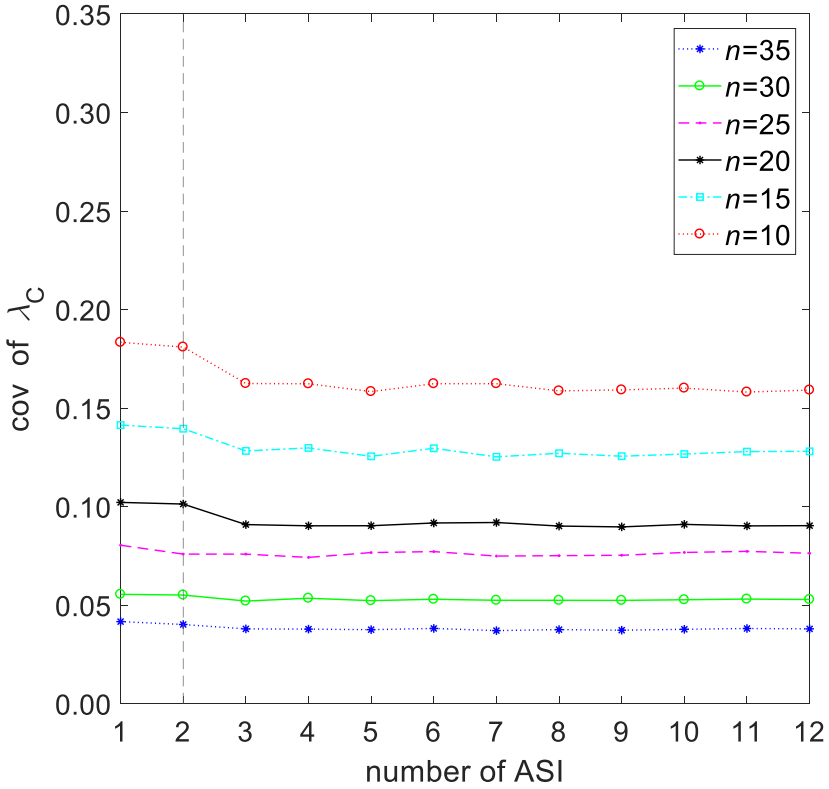
Results: trends on the collapse risk



5-storey Irregular building

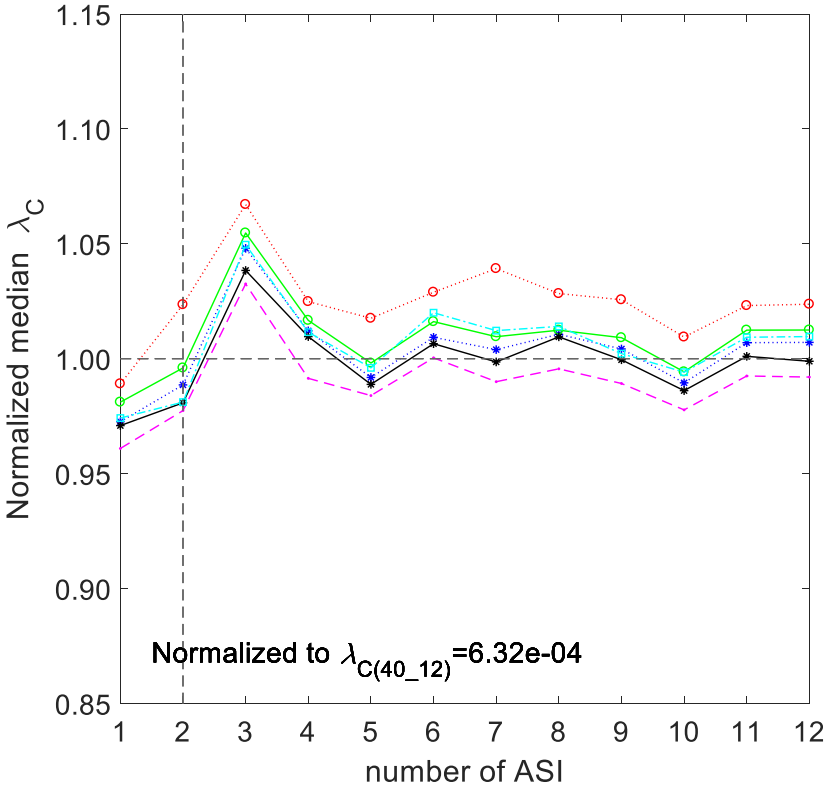
Results: effect on the collapse risk. 3-storey Regular

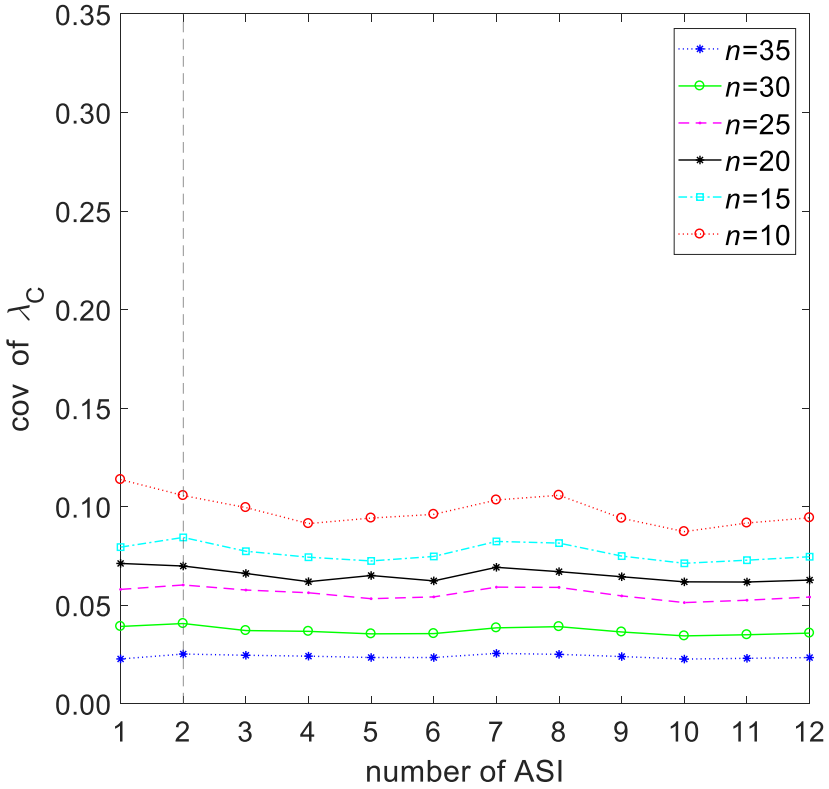




3-storey Regular building

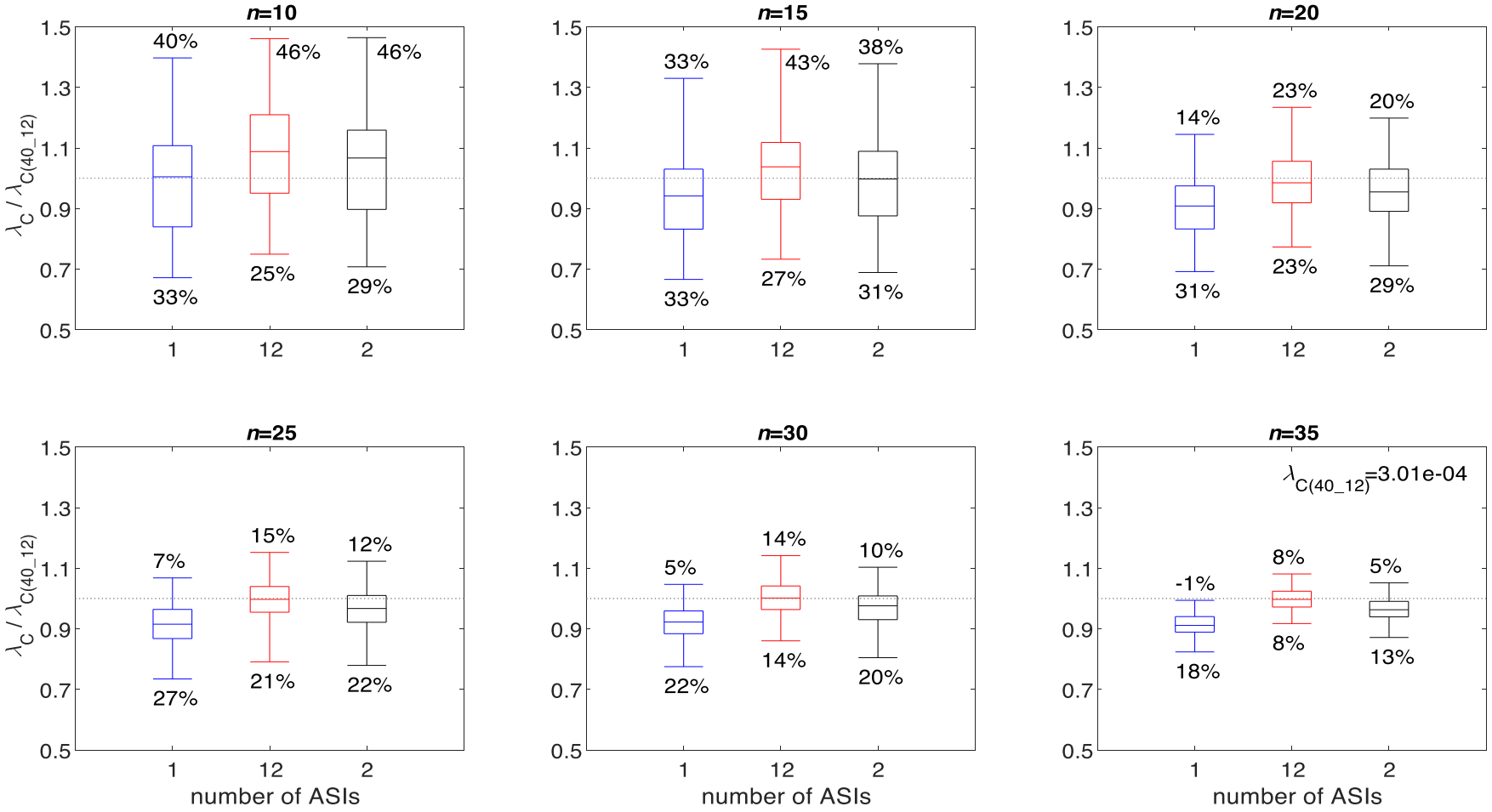
Results: effect on the collapse risk. 5-storey Irregular





5-storey Irregular building

Results: effect on the collapse risk. 3-storey Regular



3-storey Regular building

Concluding remarks

Effect of the ASI and GM group size on the collapse risk:

- The GM group size has a significant effect on the variability of the collapse risk.
- The ASI has negligible effect on the collapse risk dispersion.
- Using only 1 ASI introduces up to 10% bias in the median collapse risk, regardless of the GM group size.
- In cases where an adequate GM size is considered (thus involving a smaller demand dispersion), if only one ASI is considered, the bias introduced by this insufficient number of ASIs can lead to virtually zero probability of obtaining the reference collapse risk value.
- Suggestion: At least 20 GMs applied along 2 ASIs (0° and 90°).
- Safe choice: At least 20 GMs applied along 4 ASIs.

Thesis outline

New methods for the seismic safety assessment of structures (EC8-3)

- Introduction
  i. Definitions
  ii. Literature review
  iii. Standard provisions
  iv. Scope
- Empirical Demand assessment
  - 16ECEE (2018) + improvements
- Distribution fitting in Empirical Demand
  - 16ECEE (2018) + improvements
- Collapse Risk assessment
  - Paper under preparation
- Earthquake loss assessment
- Deterministic performance assessment and comparison with current practice
  - Comparison of guideline procedures with obtained results
- LFA
  - Bull. Earthq. Eng. (2017)
- Conclusions
  - Should we worry about the ASI? If so, how to account for it?


Thank you for
your attention