Intensity Measures for the Collapse Assessment of Infilled RC Frames

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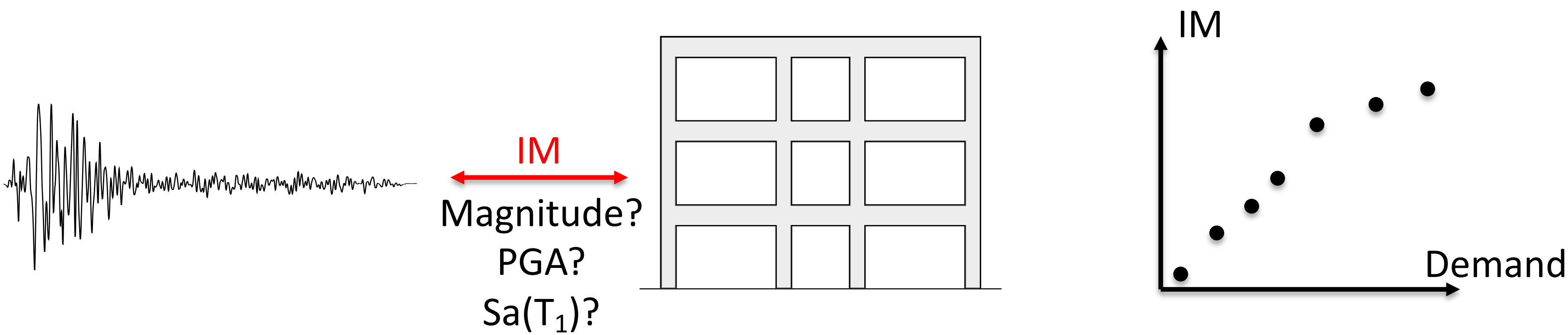
Intensity Measures

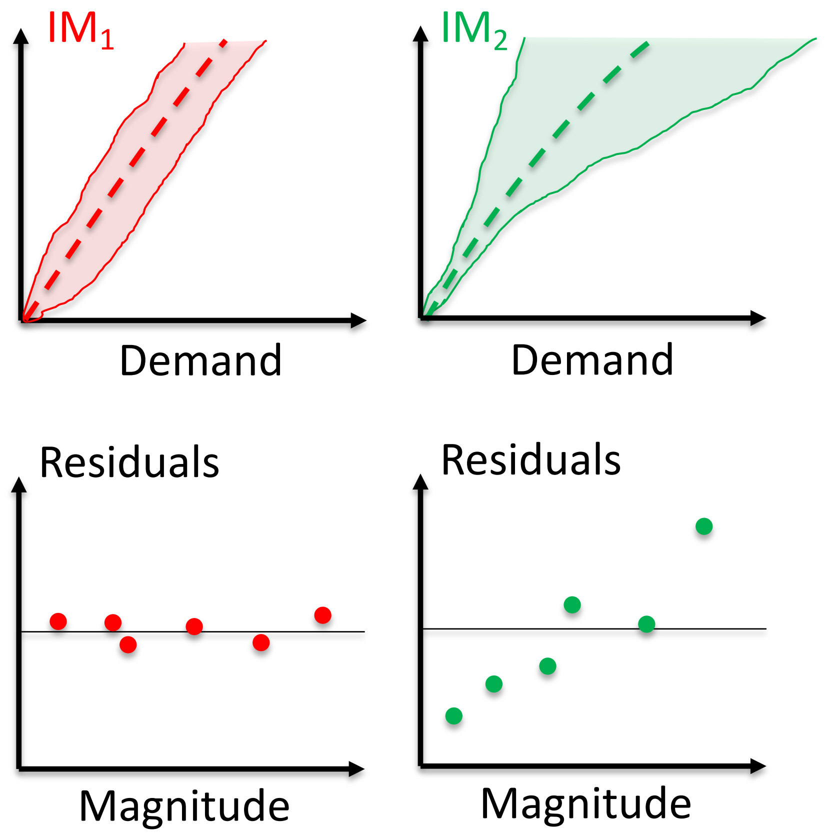
- An intensity measure (IM) is a single interface variable that connects seismological and engineering aspects of seismic assessment.



- Seismologists use ground motion prediction equations (GMPEs) and probabilistic seismic hazard analysis (PSHA) to evaluate the rate of exceedance of an IM at a specific site in a given period of time.
- Engineers, on the other hand, use the IM to examine the subsequent response of structures and to evaluate their seismic performances.

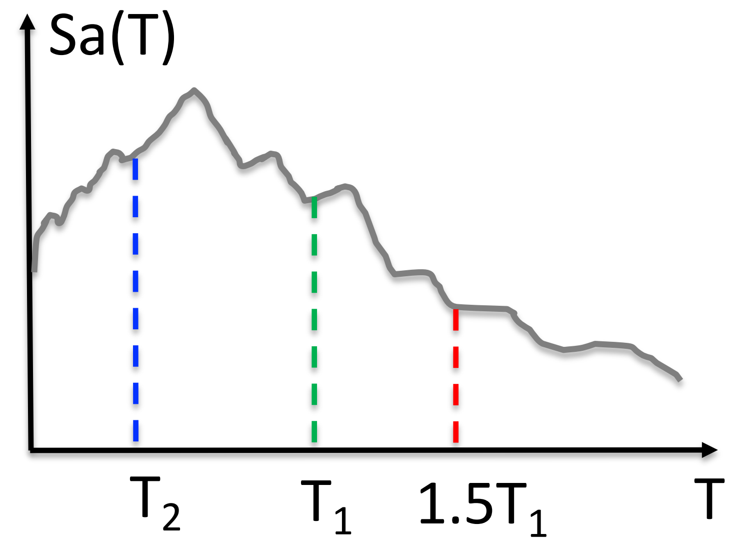
Intensity Measures

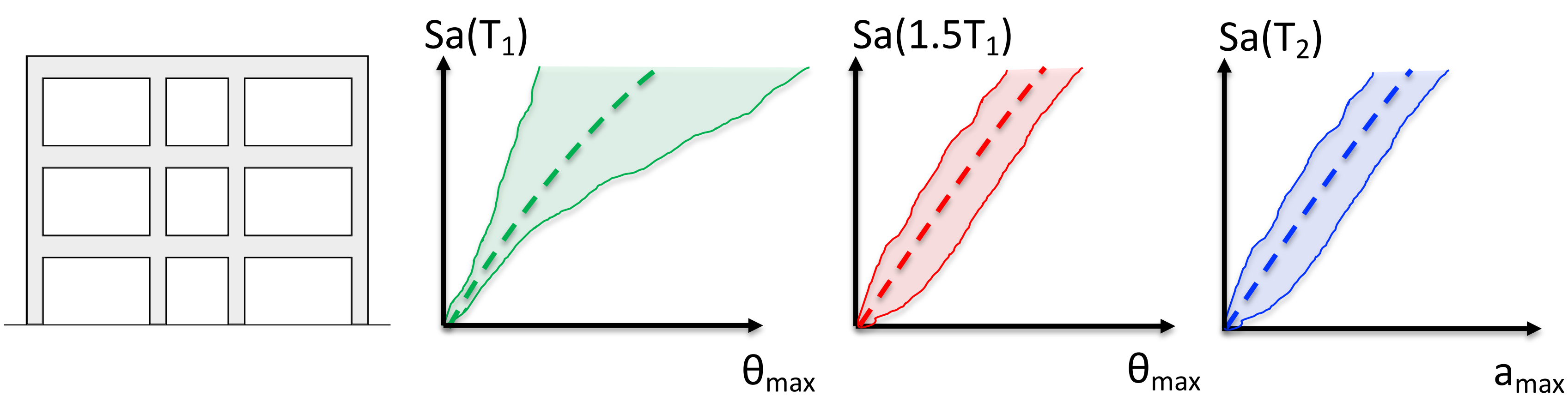
- A desirable IM ought to be:
  - *Practical - IMs for which robust and modern GMPEs are available.*
  - *Efficient - structural response should exhibit relatively low variability for the parameters of interest.*
  - *Sufficient: seismological parameters are represented without introducing any bias in results.*
- The focus of this study is on the second point relating to the *IM* efficiency with respect to the collapse assessment of infilled RC frames.



IMs for Collapse Assessment

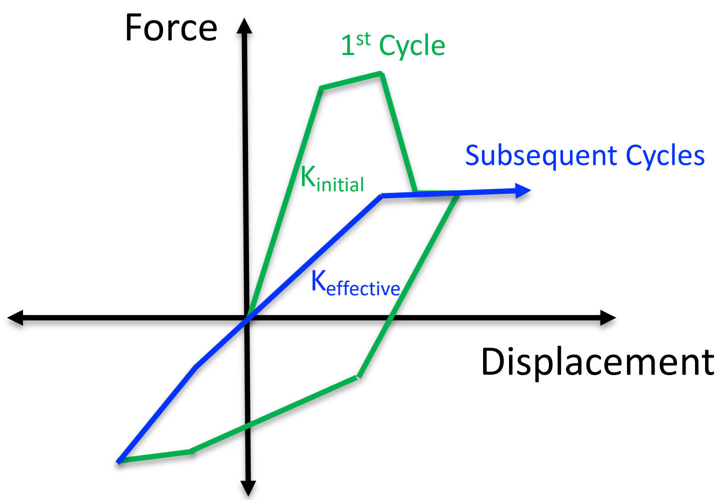
- $Sa(T_1)$ is typically adopted due to its physical meaning.
- $Sa(1.5T_1)$, is not as efficient as $Sa(T_1)$ for peak storey drift, $\boldsymbol{\theta}_{max}$ prediction in linear range.
- $Sa(1.5T_1)$ a better choice of IM for collapse assessment.
- $Sa(T_2)$ has also a goodpredictor of peak floor acceleration, $\mathbf{a}_{max}$.
- This makes the choice for a good conditioning period, T*, in ground motions selection not so simple.

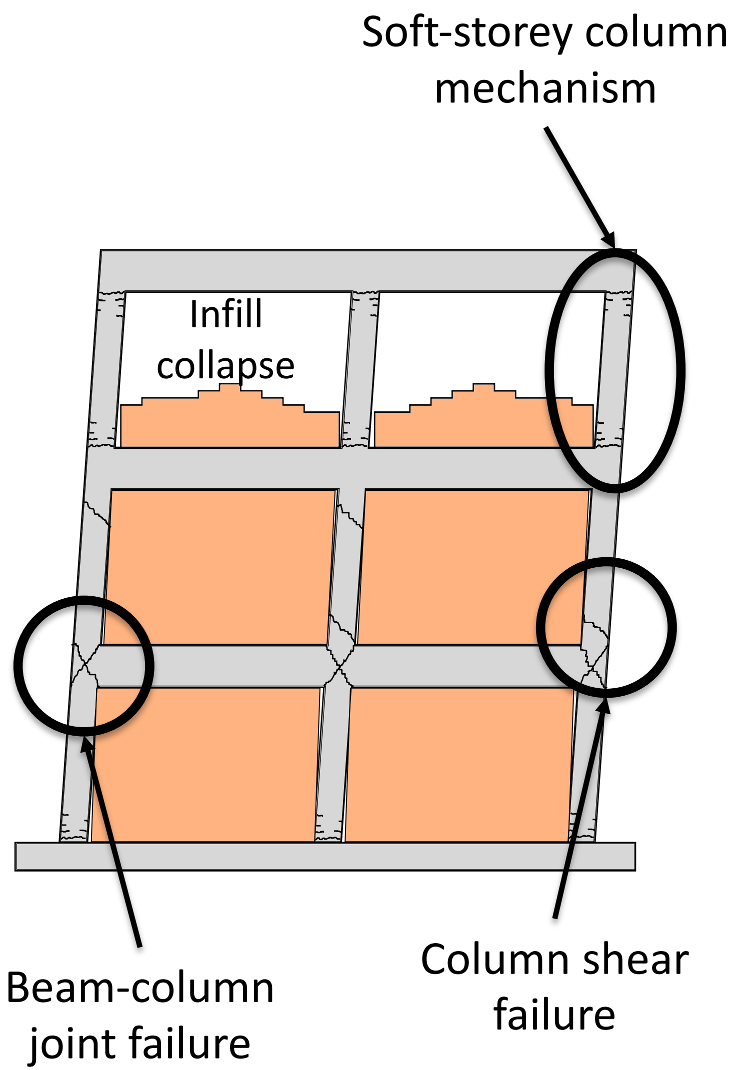




Behaviour of Infilled RC Frames

- Infilled RC frames are characterised by a high initial stiffness followed by a sharp drop in capacity following infill failure.
- Since masonry infill tends to collapse at low drifts, the resistance and stiffness tend to significantly change.
- Modal properties are significantly modified (e.g. 2-3T_1) before any significant non-linearity in the RC frame.



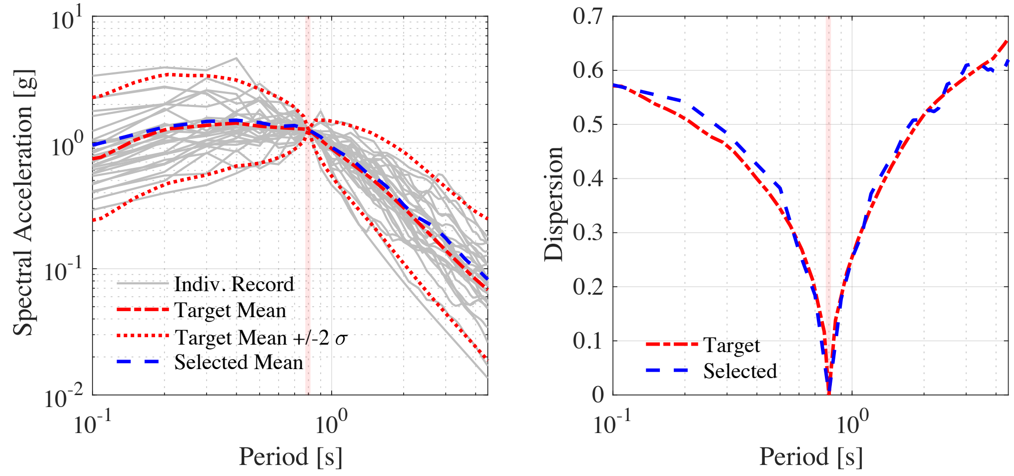


Average Spectral Acceleration

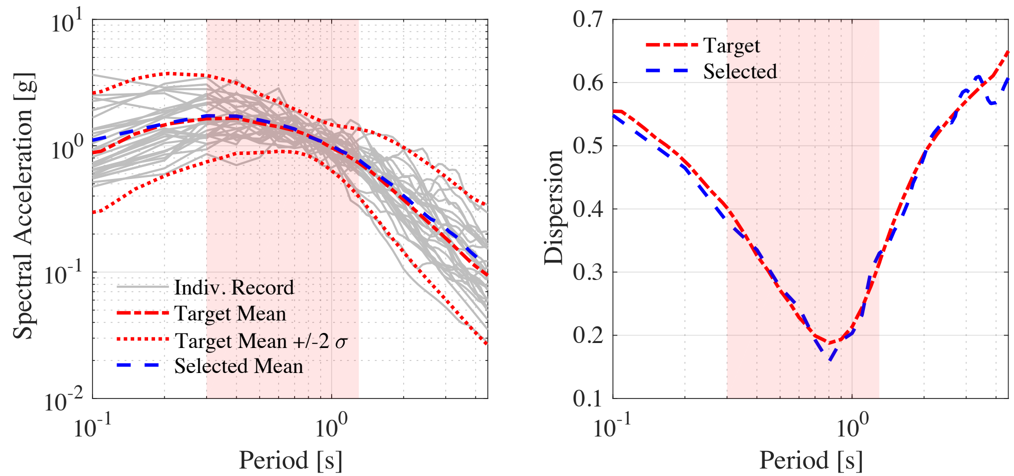
- Given the difficulty in identifying one single conditioning period, average spectral acceleration, **AvgSa**, has been proposed as a good comprise:
  - lower GMPE dispersion
  - more efficient over wider range
  - lower scaling factors required.
- Not the best IM for any single response parameter but better when evaluated collectively.
- It is a good candidate to consider here for infilled RC frames since the period elongation upon infill collapse can be accounted for.

$$AvgSa = \left[\prod_{i=1}^{n} Sa(T_i)\right]^{1/n} \quad \text{for } T_i \in [T_{lower}, T_{upper}]$$

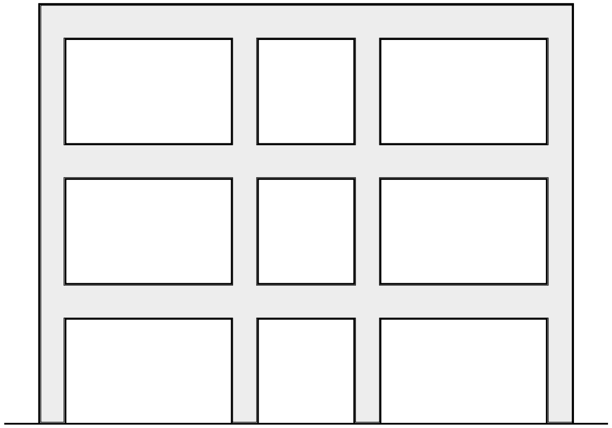
Sa(T_1): ground motions conditioned at T*



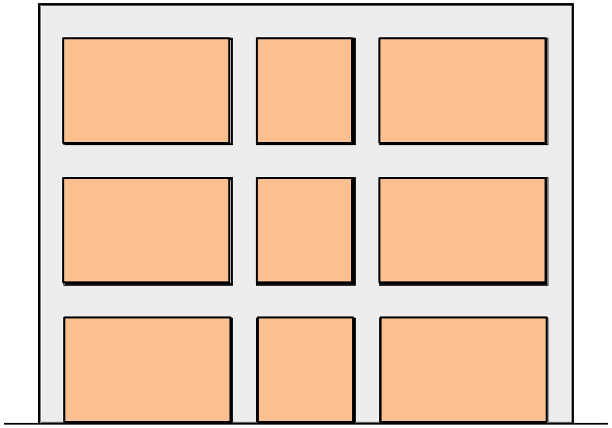
AvgSa: ground motions conditioned over [T_{lower}, T_{upper}]



Case Study Buildings



MODELLED WITHOUT INFILL



FULLY INFILLED

- 15 modelling variations were considered.
- Two types of masonry:
  - Strong (30cm hollow brick)
  - Medium (8cm hollow brick)

Typology	2 Storey	3 Storey	4 Storey	6 Storey	9 Storey
Bare Frame	0.85s	1.22s	1.52s	1.97s	2.72s
Infilled Frame (Medium Masonry)	0.19s	0.29s	0.35s	0.48s	0.74s
Infilled Frame (Strong Masonry)	0.15s	0.21s	0.29s	0.41s	0.65s

First mode periods

Case Study IMs

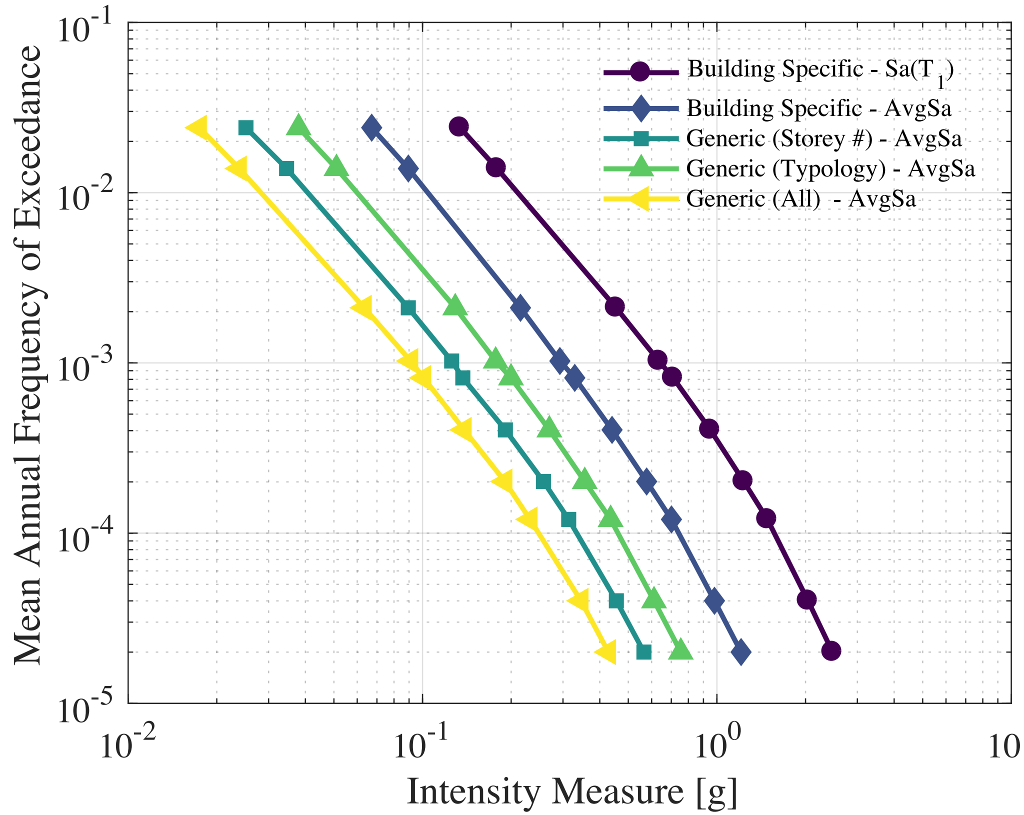
- Two IMs were adopted herein: $Sa(T_1)$ and AvgSa.
- Using these IMs, two IM types were established:
  - Building-specific AvgSa
  - Generic AvgSa

IM type	Notation	IM	Period range
Building specific IMs	$Sa(T_1)$	$Sa(T_1)$	-
	AvgSa	AvgSa	Bare frames: T_2 to $1.5T_1$ Infilled frames: $1.2T_2$ to $3T_1$
Generic IMs	Generic (Storey #)	AvgSa	Min. to max of AvgSa's period range for all **same-height** buildings
	Generic (Typology)	AvgSa	Min. to max of AvgSa's period range for all **same-typology** buildings
	Generic (All)	AvgSa	Min. to max of AvgSa's period range for **all** buildings
Note: the periods for the computation of AvgSa have a 0.1s spacing in the corresponding period range			

Site Hazard

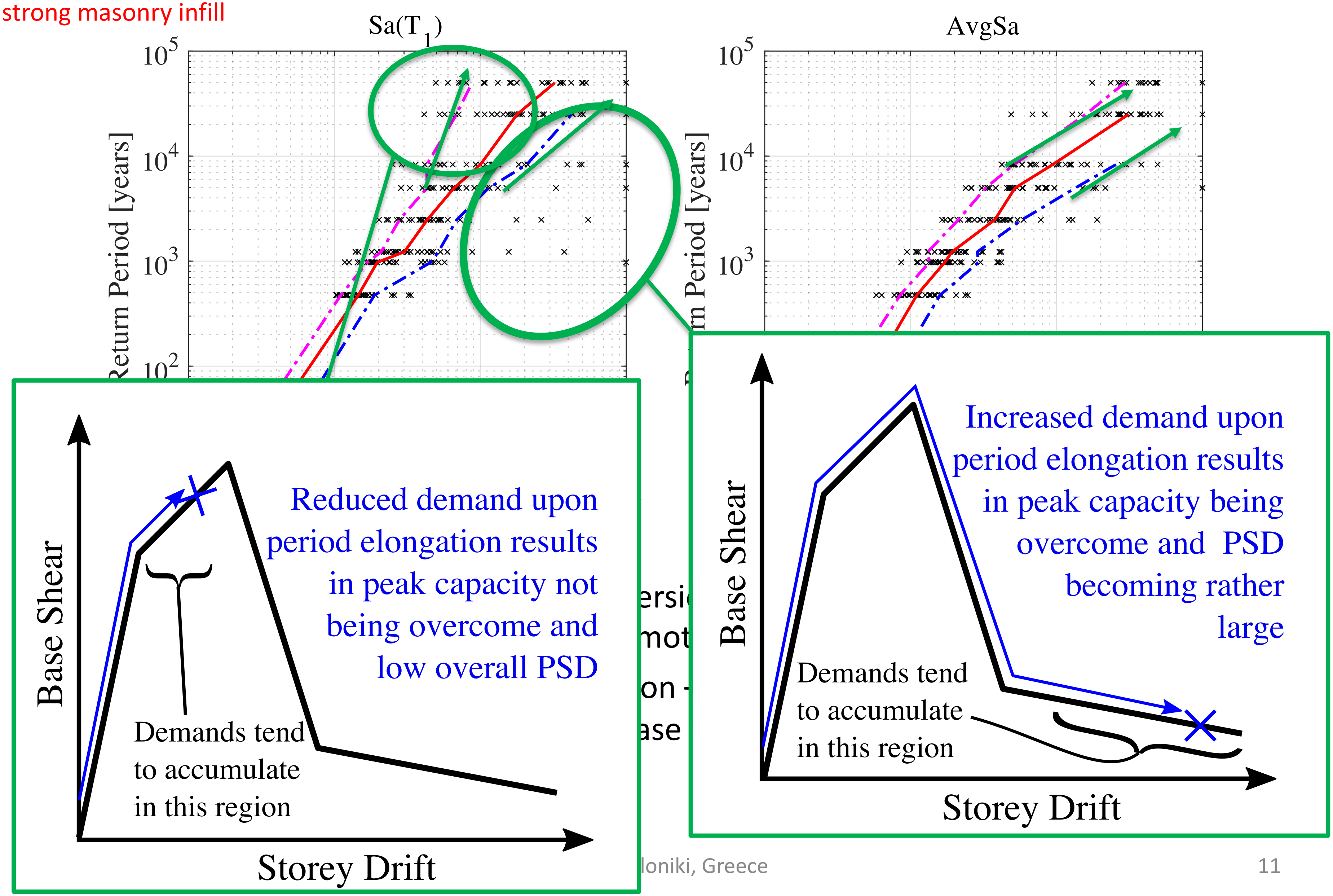
- A site on rock was selected in the Italian city of L'Aquila.
- OpenQuake engine was used to perform the seismic hazard computations.
- Analysis was based on the SHARE Project area source model and the GMPE proposed by Boore and Atkinson (2008).
- 10 return periods considered and 30 ground motion pairs selected at each level.
- Scaling factors limited to 4.0.

Hazard curves for 6-storey frame wth strong masonry infill

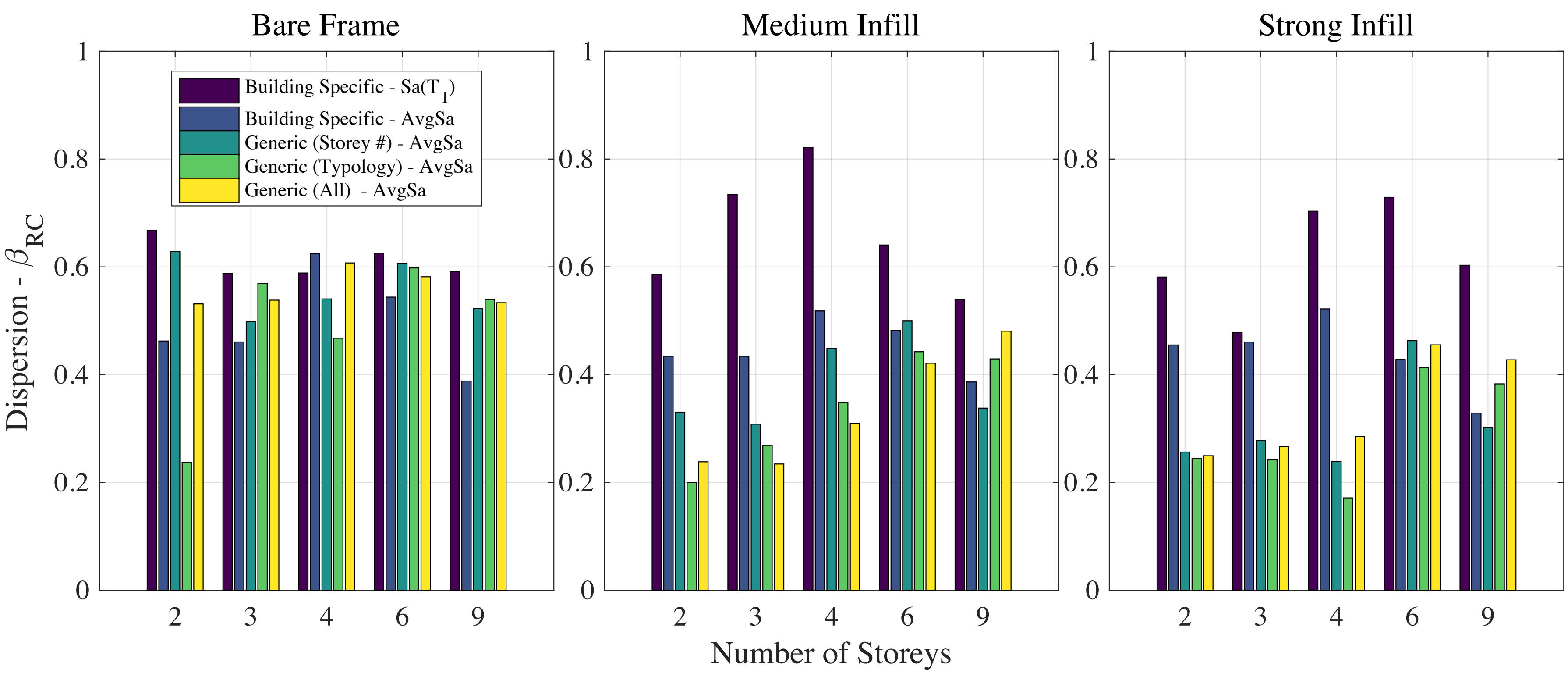


6-storey frame wth strong masonry infill

Storey Drift Demand Evaluation

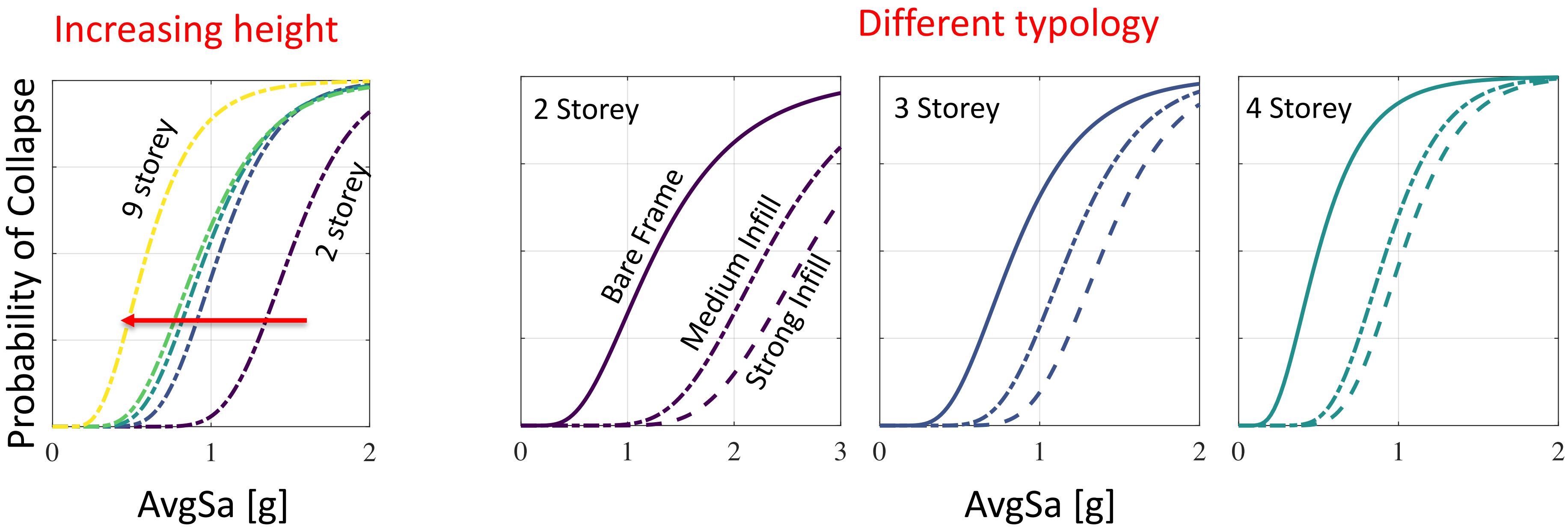


Collapse Performance



- AvgSa provides a slightly more efficient estimate than Sa(T_1) for the bare frames since dispersions are similar.
- AvgSa is a much more efficient predictor of collapse for infilled RC frames.
- For the generic IMs, the generic AvgSa is see to give a comparable level of efficiency when compared to the building-specific AvgSa.

Generic AvgSa IMs



- Using a generic definition of AvgSa allows building fragilities to be compared but offers a good degree of efficiency.
- Impacts of different aspects relating to collapse can be easily observed.
- Useful for portfolio assessment, where IMs like PGA have traditionally been used.
- PGA is known to correlate poorly with structural response compared to Sa(T_1).
- Generic AvgSa offers similar similar of efficiency as Sa(T_1) but gives adequate genericness.

Concluding Remarks

- In terms of drift demand:
  - $Sa(T_1)$ dispersion is lower than AvgSa at low intensities of elastic response.
  - AvgSa is a superior predictor of infilled RC frame response for higher intensities.
- For collapse fragility estimation:
  - Dispersion is typically much lower for AvgSa than $Sa(T_1)$.
- For generic definitions of AvgSa:
  - Applicable to large groups of structures and able to maintain a comparable level of efficiency when compared to building-specific IMs.
  - Represent an improvement compared to other IMs like PGA that are generic enough to be used for all structures, but are known to be poorly correlated to structural response of most buildings.

Thank you