Implications of a More Refined Damage Estimation Approach in the Assessment of RC Frames

Gerard J. O'Reilly
IUSS Pavia, Italy

Timothy J. Sullivan
University of Canterbury, New Zealand

André Filiatrault
IUSS Pavia & SUNY Buffalo

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IUSS
Scuola Universitaria Superiore Pavia

Background & Motivation

- Major steps made in the assessment of buildings over the past years.
- The advent of the PEER PBEE methodology has moved discourse from defining performance in terms of base shear, drift to that of economic impact and downtime, for example.
- Current “state-of-practice” in the implementation of loss estimation studies contain a number of assumptions.

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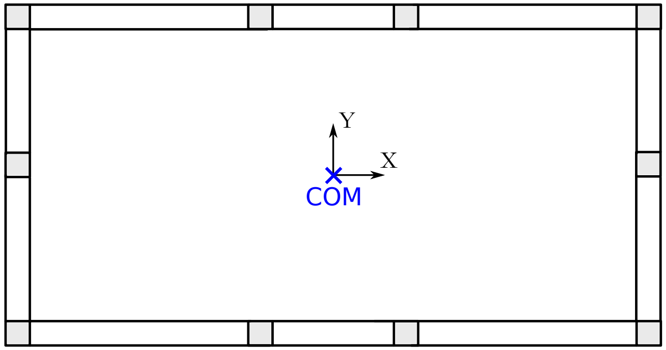

Application of the PBEE methodology (e.g. FEMA p58) typically linked to regular, symmetric case study structures

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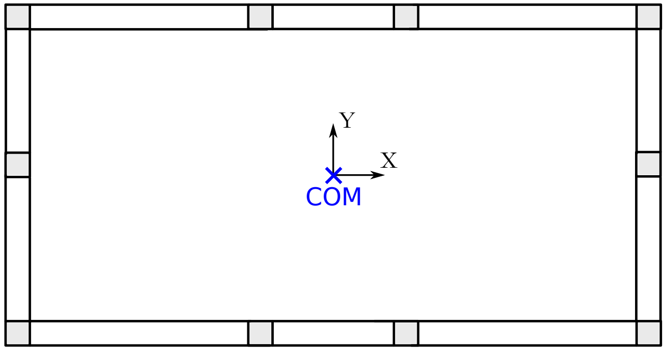
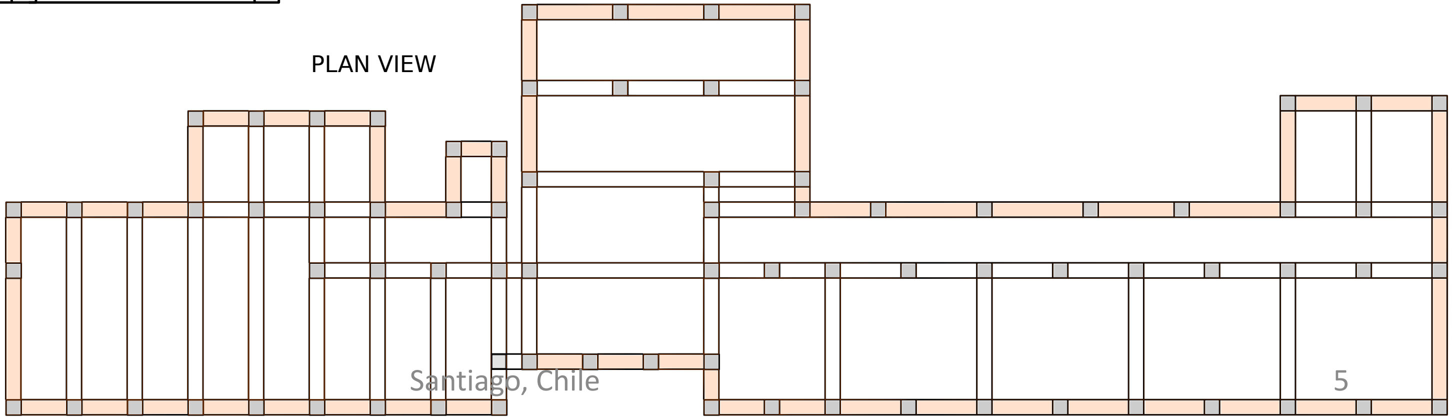


Application of the PBEE methodology (e.g. FEMA p58) typically linked to regular, symmetric case study structures

But what about irregular structures, with uneven bay lengths, non symmetry and torsionally dominated?

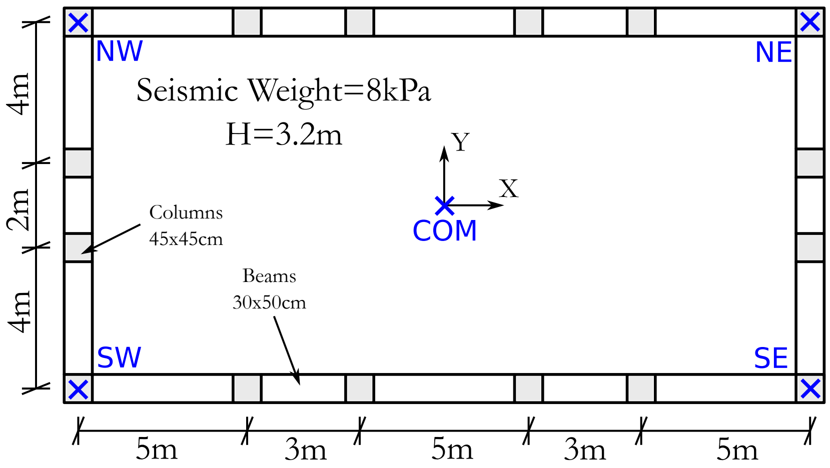
PLAN VIEW



Overview

- This presentation will expand on 3 main points related to this:
  1. Examining the impact of structure torsionality on the estimation of RC frame damage.
  2. The potential impact on the loss estimation.
  3. Other aspects to consider in RC frame assessment.

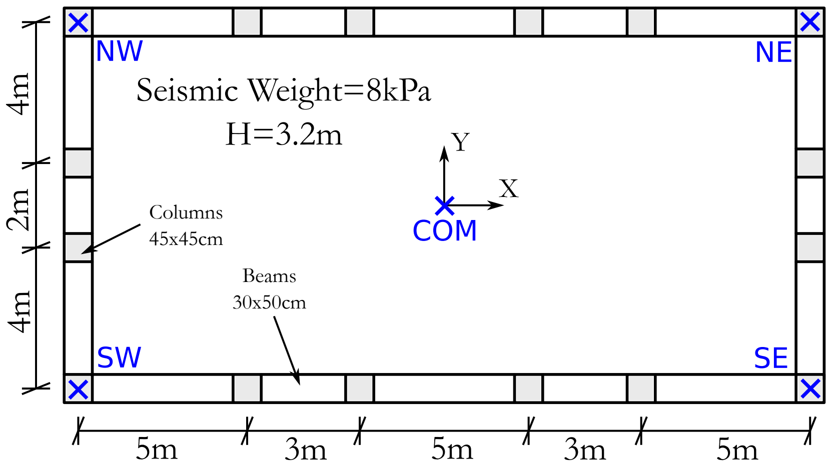
Case Study Buildings



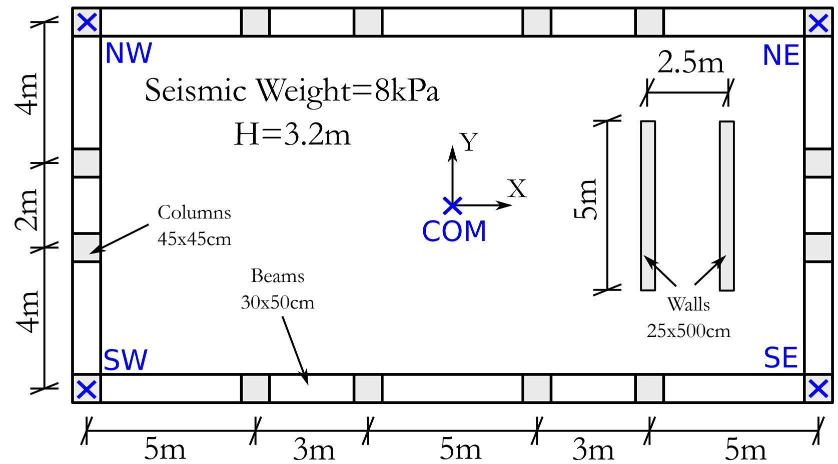
Frame A - Symmetric

- Frames designed using displacement based design (DDBD) to meet the requirements of Eurocode 8 with a PGA=0.4g.
- Frame B is the same as Frame A but with an addition set of RC walls to induce a torsional response of the frames.
- The effects of this torsional response will be investigated later with respect to the symmetric response.

Case Study Buildings



Frame A - Symmetric



Frame B - Asymmetric

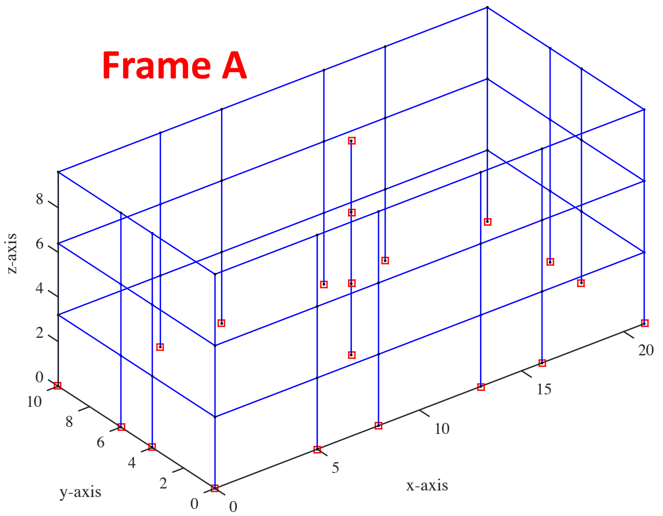
- Frames designed using displacement based design (DDBD) to meet the requirements of Eurocode 8 with a PGA=0.4g.
- Frame B is the same as Frame A but with an addition set of RC walls to induce a torsional response of the frames.
- The effects of this torsional response will be investigated later with respect to the symmetric response.

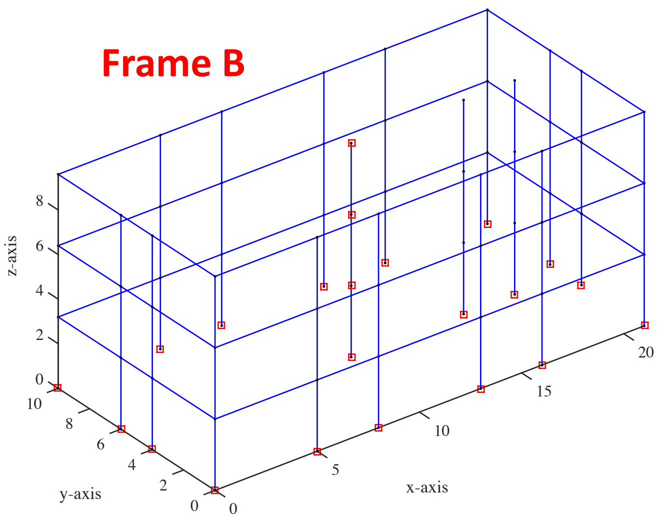
Numerical Modelling

- RC member hysteresis implemented with a lumped plasticity approach using the Ibarra-Medina-Krawinkler hysteretic model available in OpenSees.
- Hysteretic parameters computed from Haselton et al. [2008] for ductile RC members.

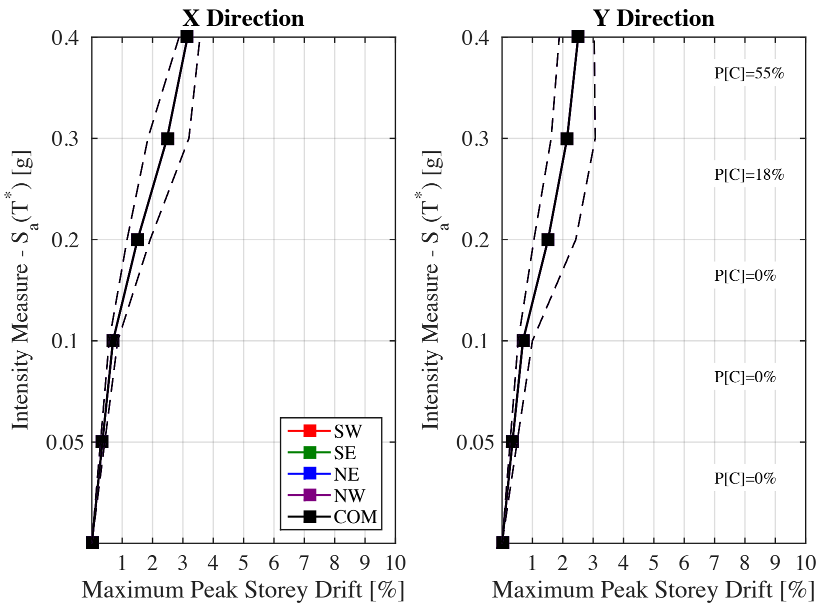
First mode period in X and Y direction

Layout	3 Storey	
	T_X	T_Y
Frame A	0.94s	0.93s
Frame B	0.94s	0.49s

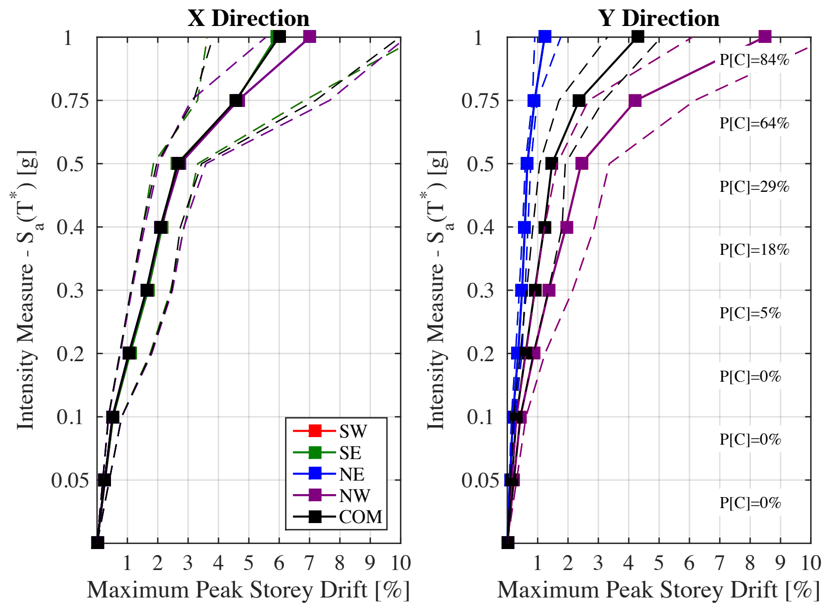




Incremental Dynamic Analysis



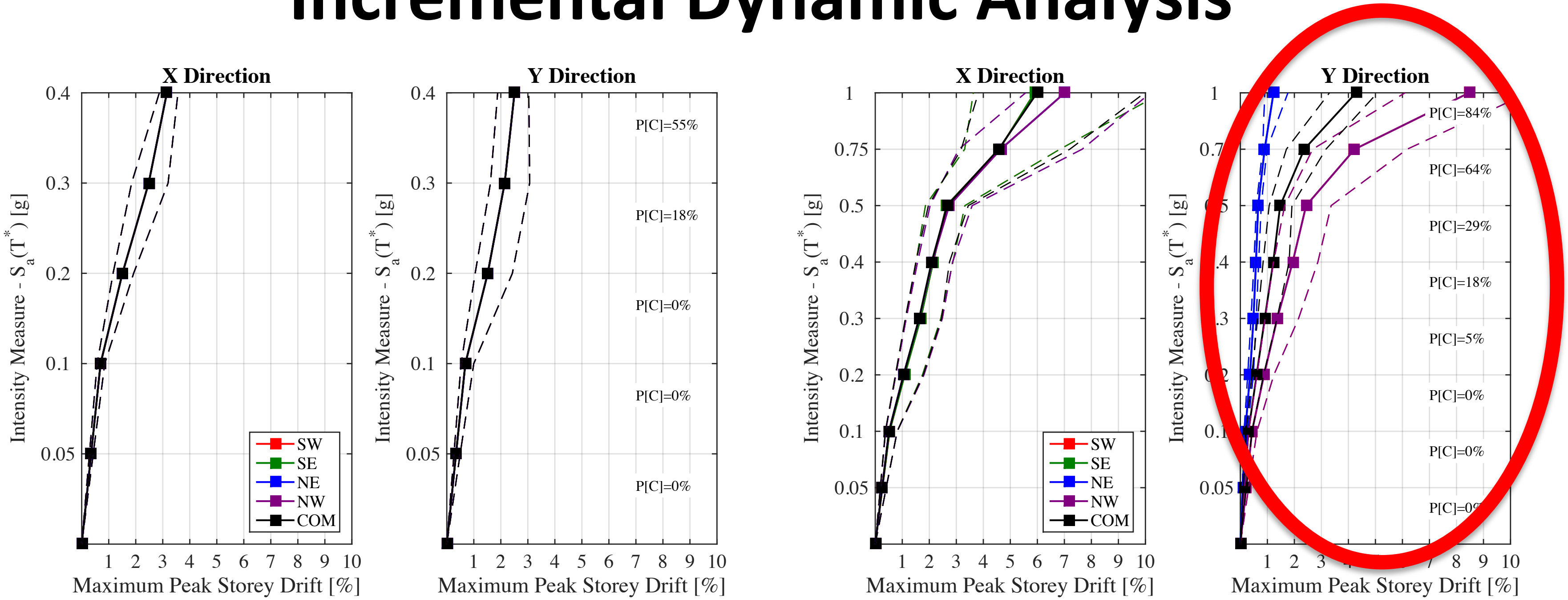
Frame A - Symmetric



Frame B - Asymmetric

- Incremental dynamic analysis (IDA) was performed using the FEMA P695 record set to characterise the behaviour of the frames with respect to IM.
- The IM used in this case was Sa(T*).

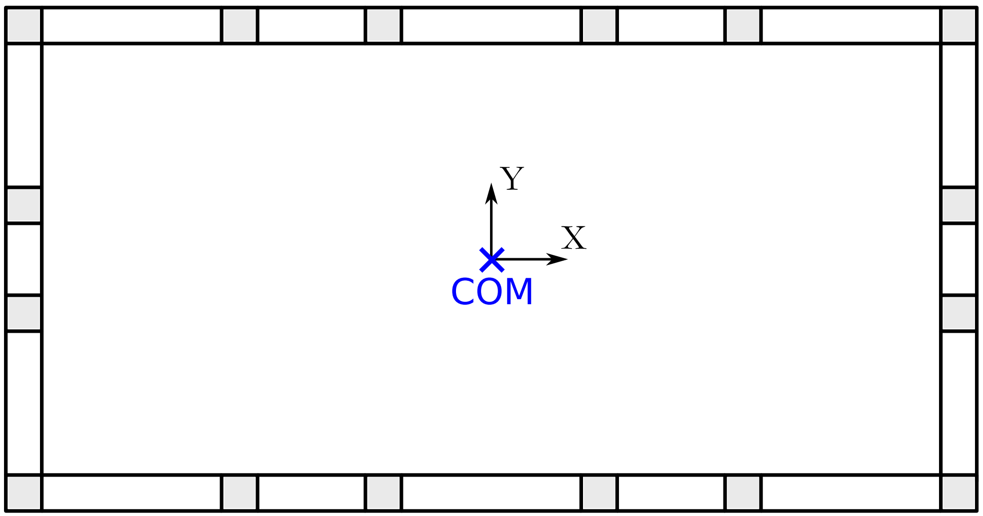
Incremental Dynamic Analysis



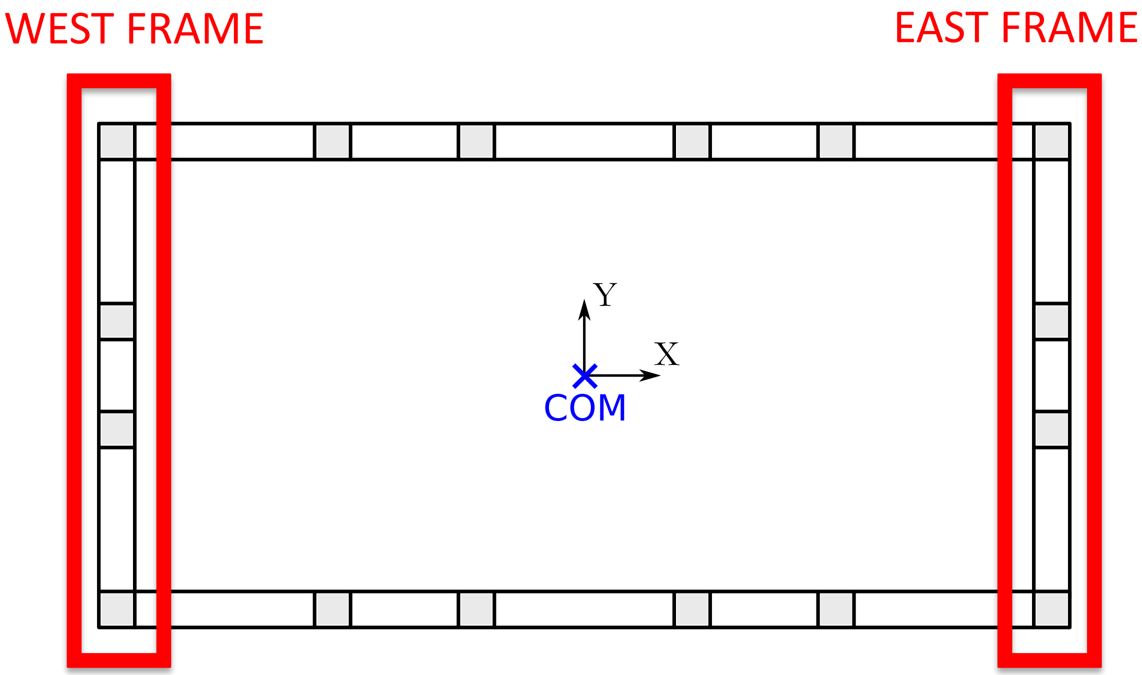
Frame A - Symmetric **Frame B - Asymmetric**

- Incremental dynamic analysis (IDA) was performed using the FEMA P695 record set to characterise the behaviour of the frames with respect to IM.
- The IM used in this case was Sa(T*).
- The symmetric response of Frame A noted, whereas the increased response of the west end of Frame B in the Y direction is noted.

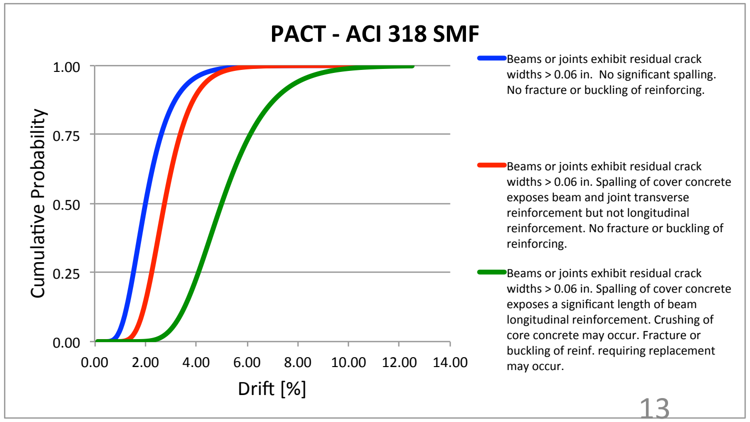
Damage Assessment



Damage Assessment



- For both frames, A and B, the damage to the frames on the west and east ends in the Y direction of response is assessed.
- Damage assessed using the fragility function set available in PACT.



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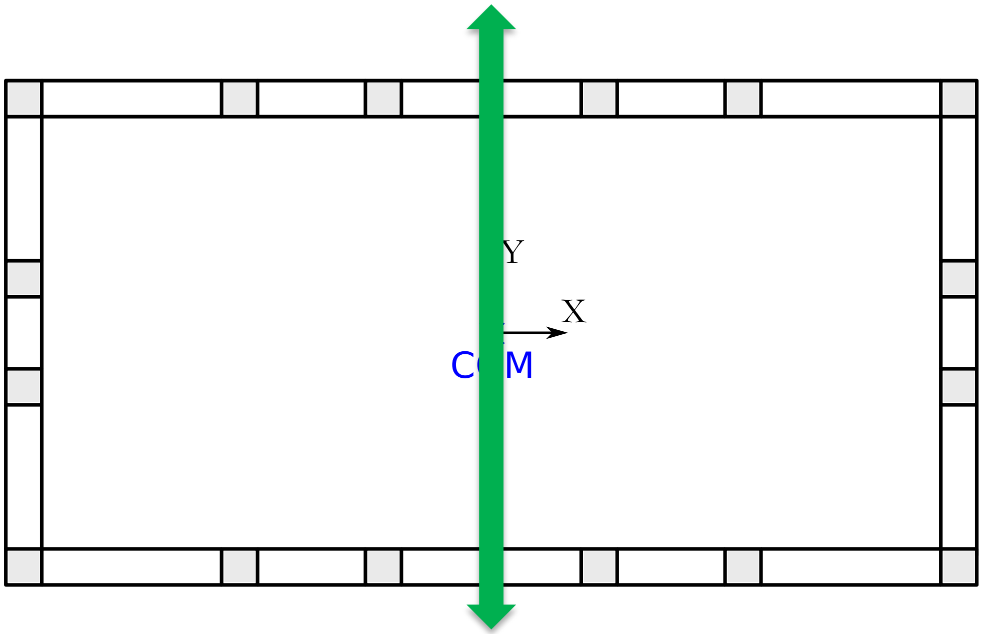
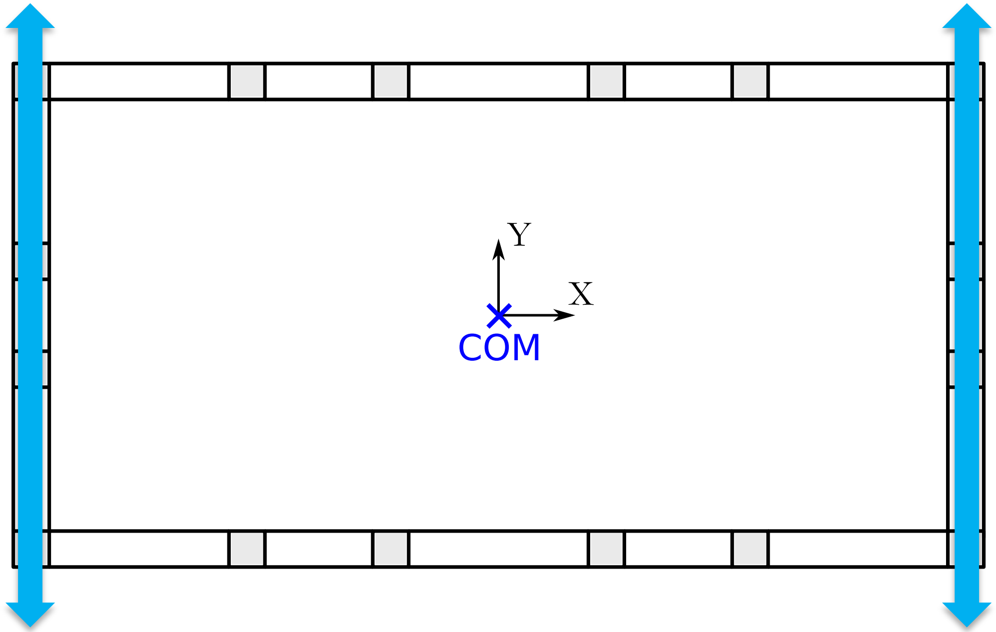


Method 1 – the damage in the frames is estimated by taking the demands at the COM

- For both frames, A and B, the damage to the frames on the west and east ends in the Y direction of response is assessed.

Damage Assessment



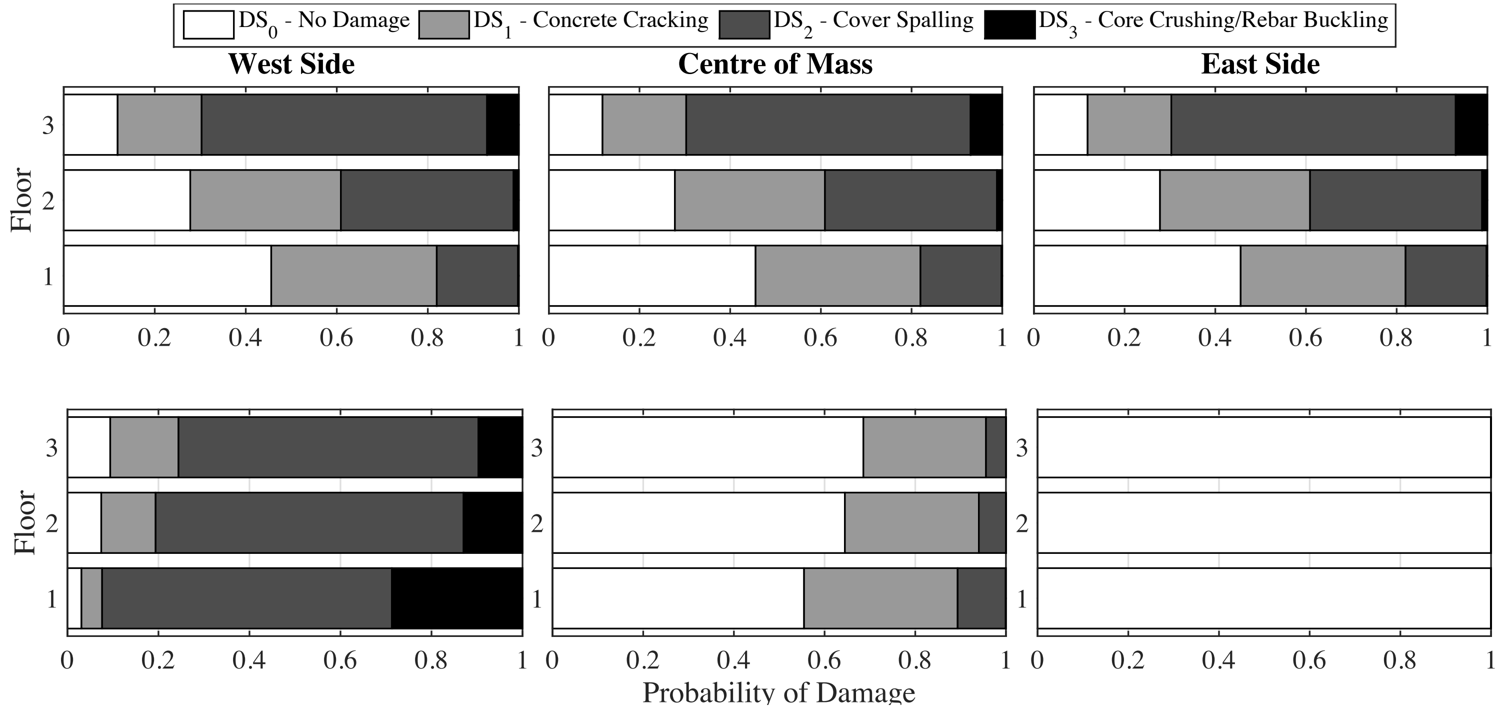
Method 2 – the damage in the frames is estimated by taking the demands at the actual gridline of the frames.

- For both frames, A and B, the damage to the frames on the west and east ends in the Y direction of response is assessed.

Damage Assessment

Frame A – Symmetric

Frame B – Asymmetric



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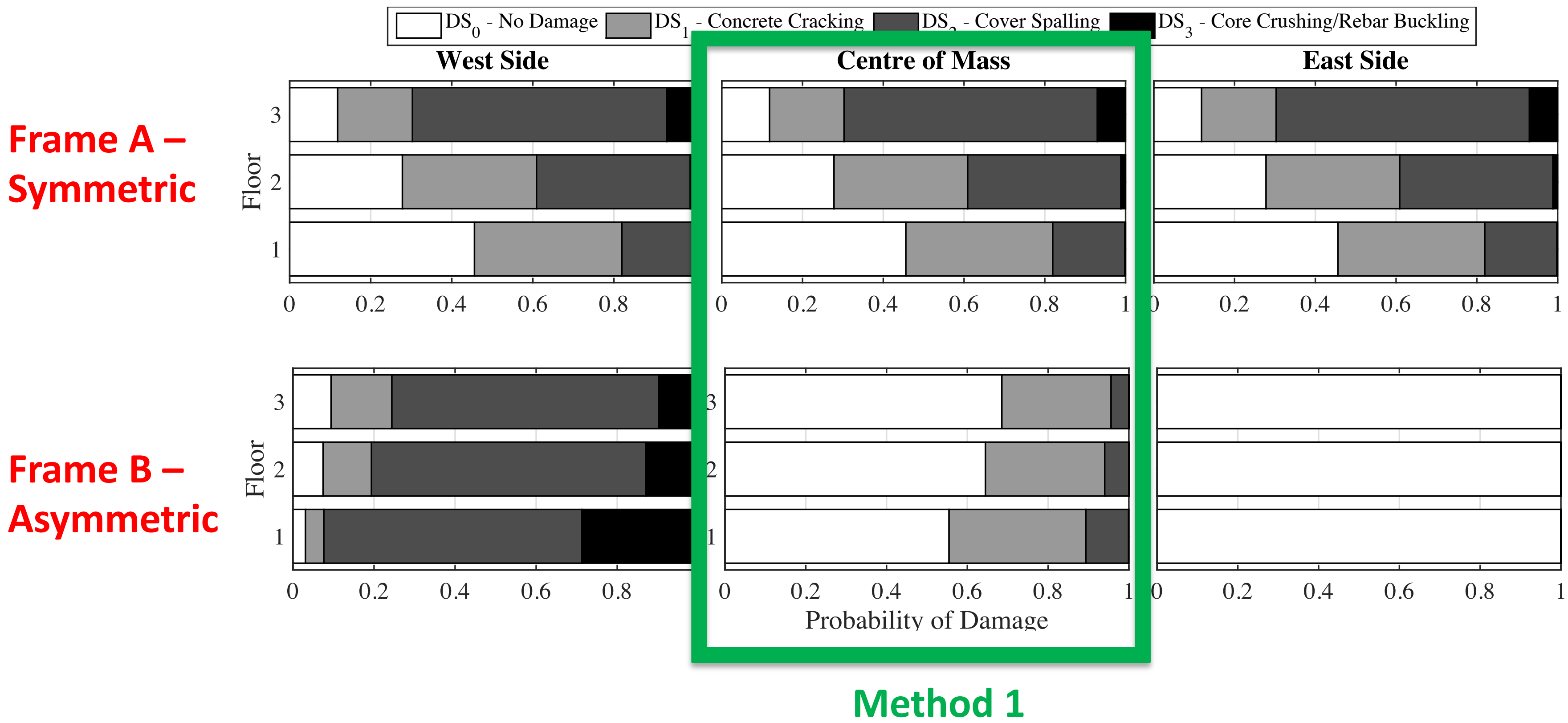

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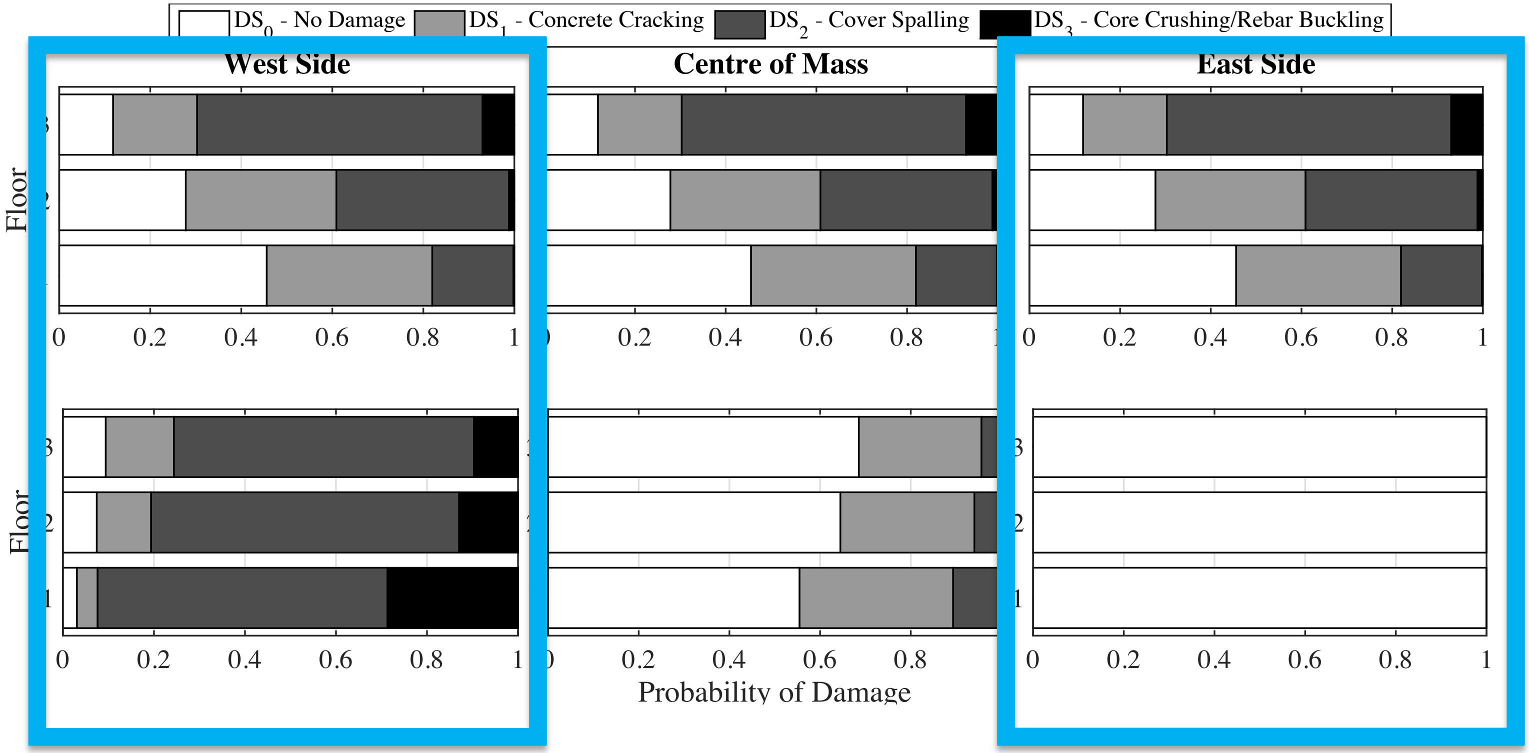
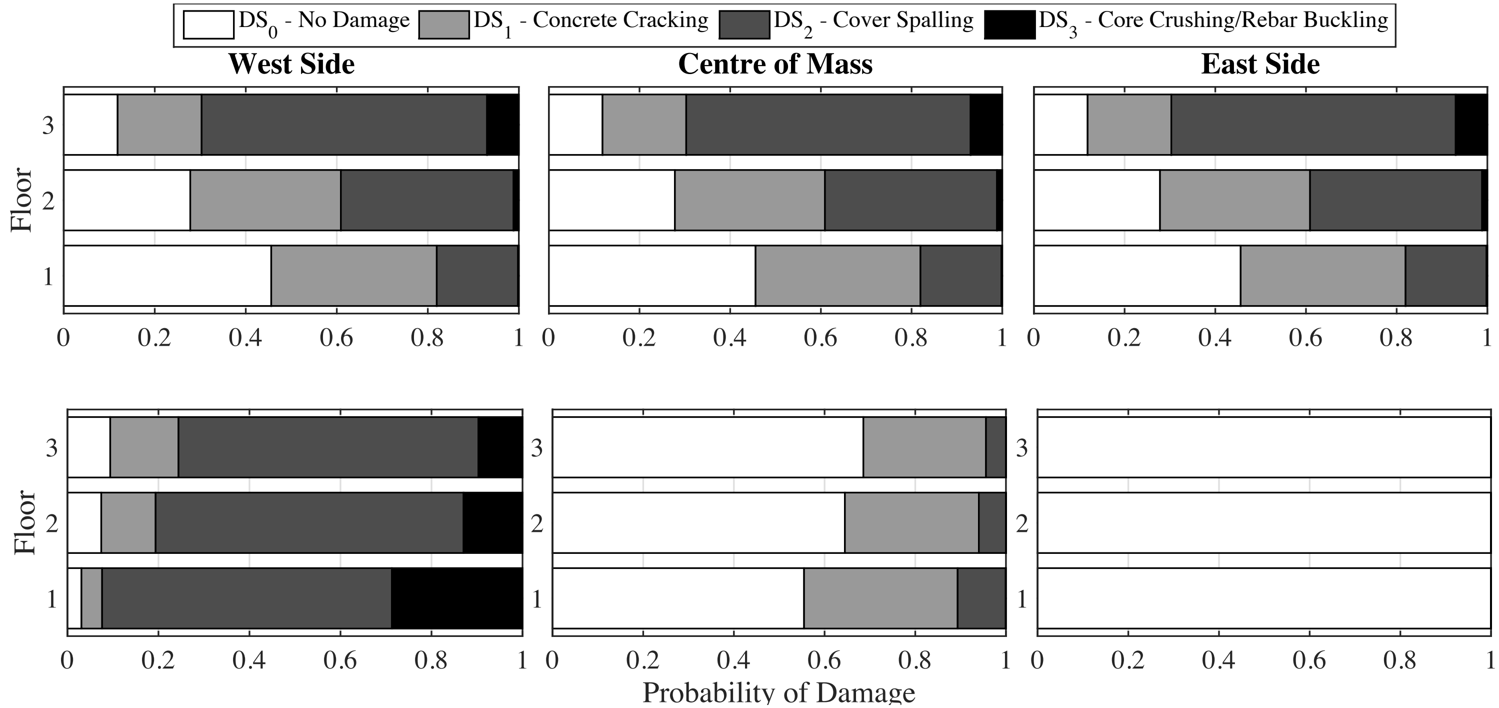


Method 2

Damage Assessment

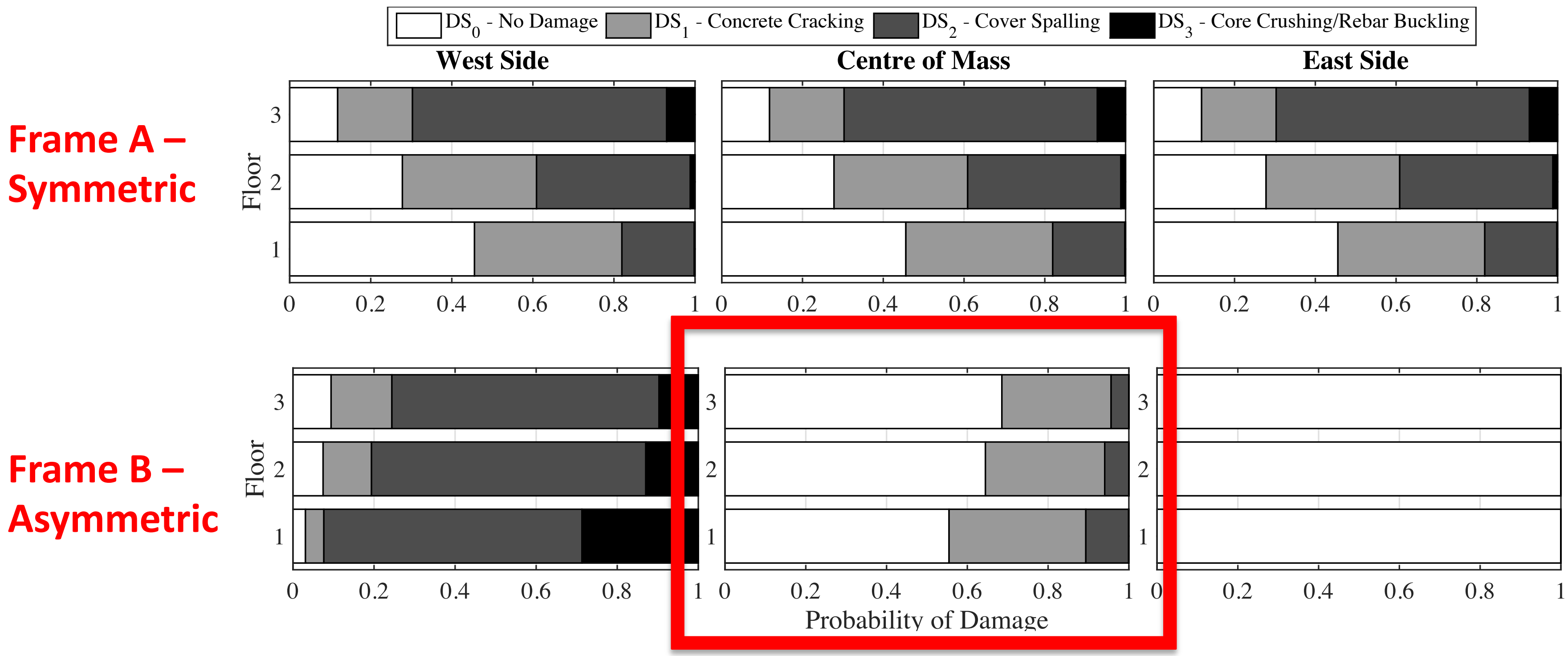
Frame A – Symmetric

Frame B – Asymmetric



- Comparing the results of the damage assessment shows some disparity between the two approaches.
- The heavy damage on the west side of Frame B shows how using the demands at the COM can be unconservative.
- Highlights the need for care when assessing more irregular structures.

Damage Assessment



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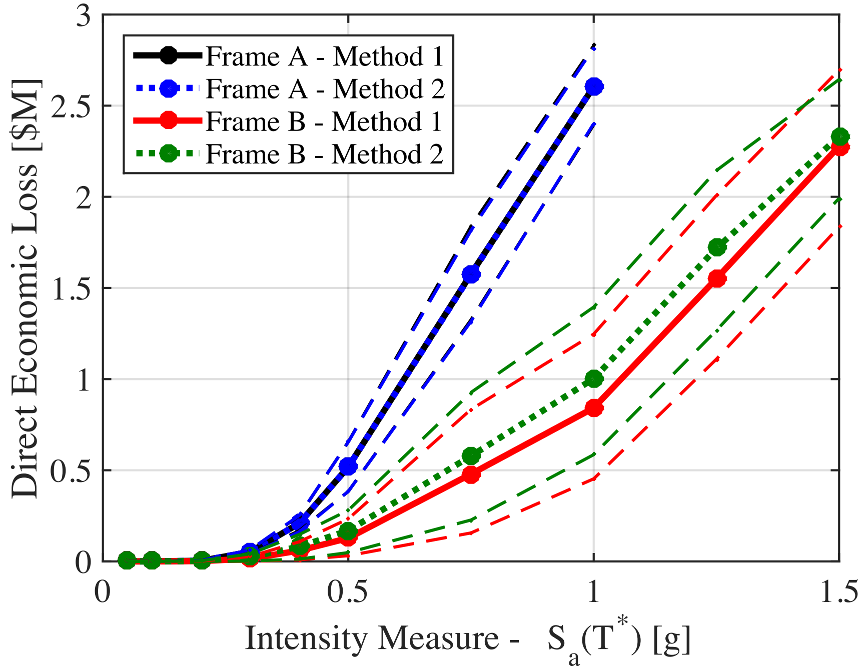
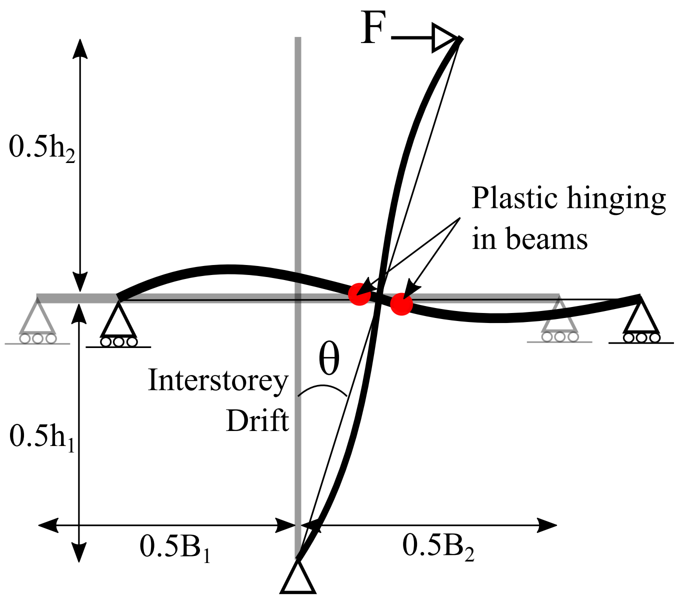
Loss Estimation



- If we assume a damageable inventory for the RC frame only, we can examine the impact on the expected losses.
- Using Method 1 (i.e. using COM demands) result in up to a 30% underestimation of the expected loss.
- This disparity is especially prevalent in the lower intensities, which when integrated with the hazard curve can have major implications on quantities such as expected annual loss (EAL).

Other Aspects and Future Directions



- Fragility functions for ductile RC beam-column joints typically derived from sub-assemblies like the one shown.
- These inherently assume mid-height contraflexure points and equal bay lengths.

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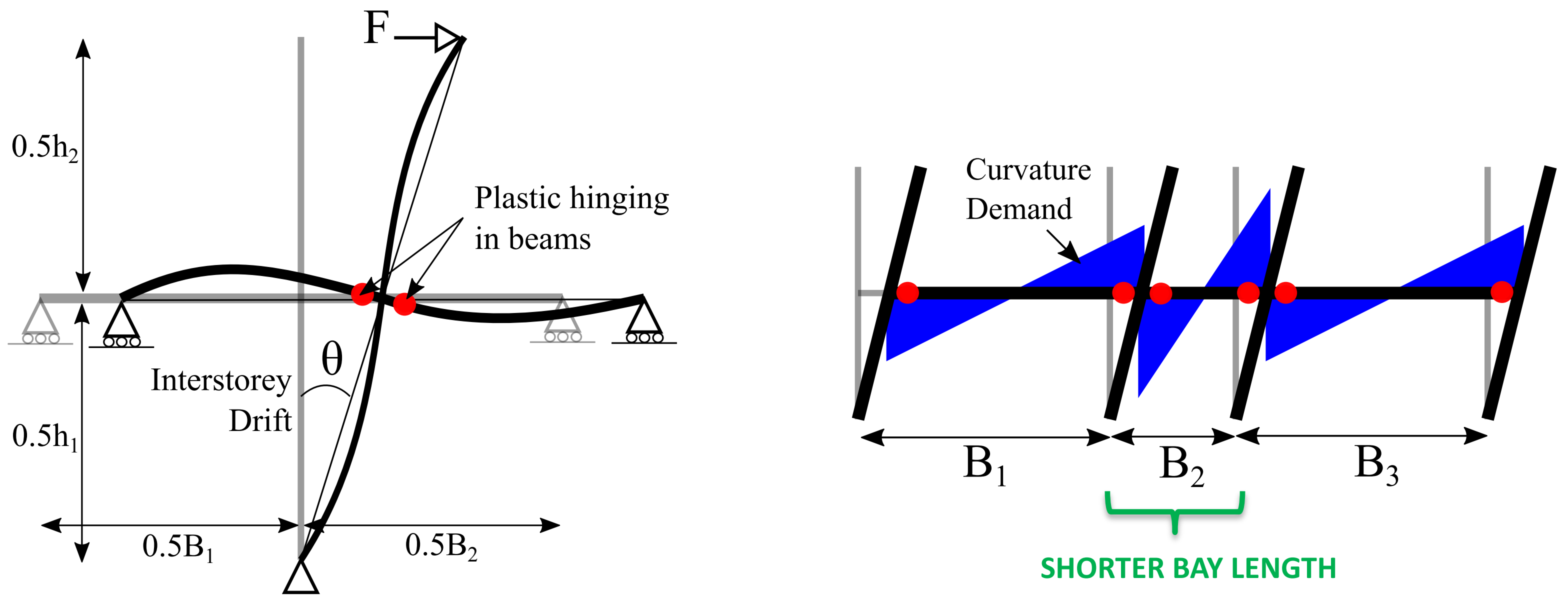

- Fragility functions for ductile RC beam-column joints typically derived from sub-assemblies like the one shown.
- These inherently assume mid-height contraflexure points and equal bay lengths.
- If we consider that the interstorey drift is a more indirect measure of damage and that beam hinge curvature demands to be more refined, what impact does this have?
- In cases of unequal bay lengths the damage to shorter bay lengths can be underestimated.

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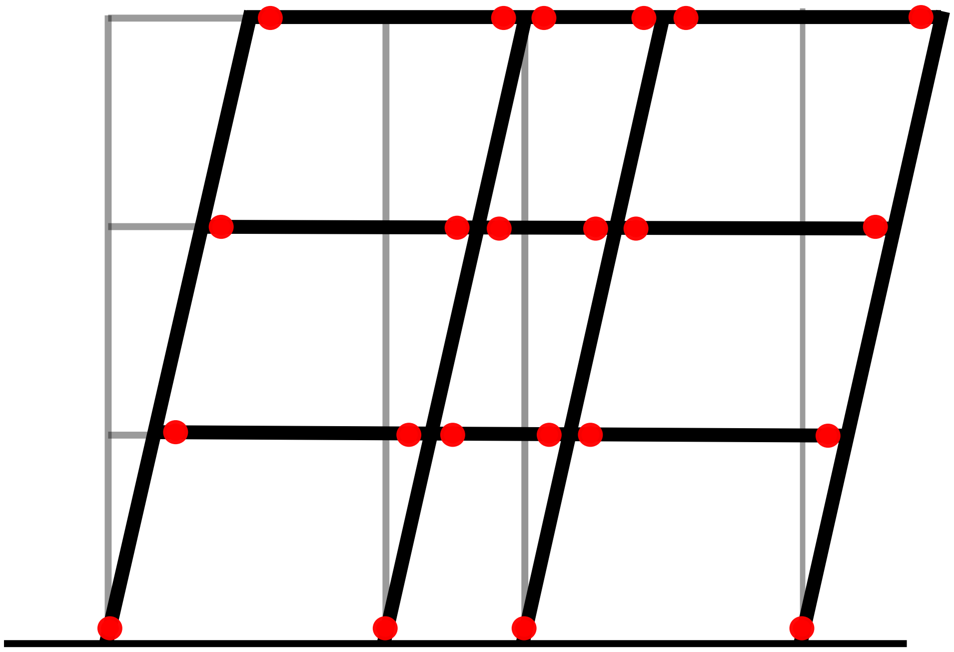

- Drift is often used as a demand parameter in assessment, but what does this mean?
- Interstorey drift and storey drift not necessarily the same thing.
- Interstorey drift is a good demand parameter for beam column joints, whereas storey drift is more suitable for non-structural elements such as partitions.
- Which ones are being used? Do they make sense and above all, are they consistent with the fragility function's definition?

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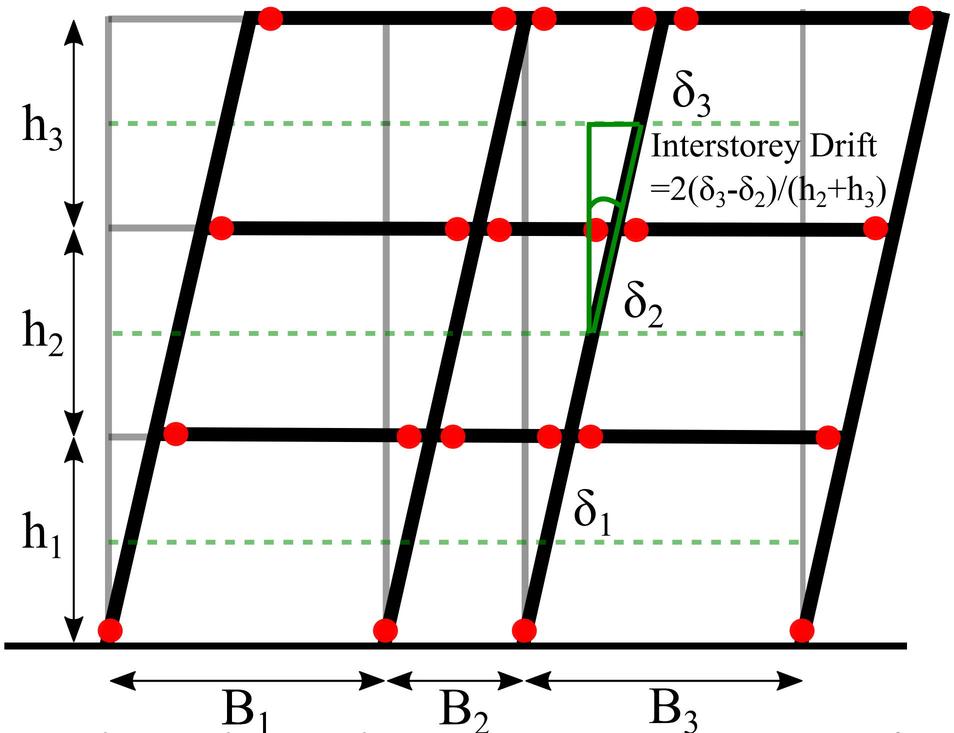

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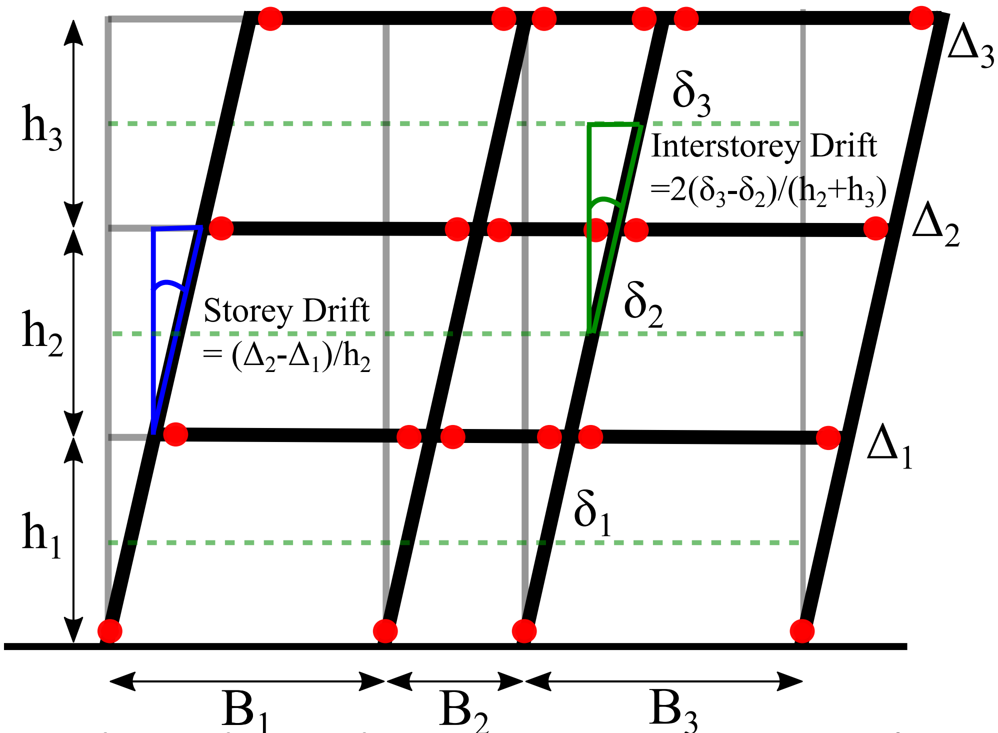

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Concluding Remarks

- This paper has highlighted some of the implications of some more refined considerations when assessing existing buildings.
- A case study building modelled both with and without torsionality was used to illustrate the potential impacts of simplifying assumptions.
- This impact of irregularity was extrapolated to loss estimations where differences of up to 30% were observed.
- Overall, this paper highlights the need for care when assessing existing structures with various degrees of irregularity.
- Finally, other aspects such as the derivation of fragility functions and definition of drift demand were highlighted.

Thank you for your attention

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