PROBABILISTIC SEISMIC VULNERABILITY ASSESSMENT OF "GAIOLEIRO" BUILDINGS

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Motivation

- Masonry buildings were built for many centuries based on the available materials and empirical provisions.
- "Gaioleiro" buildings (19-20th centuries) is the typology with the highest structural weaknesses of the building stock of Lisbon.

Objectives of the PhD research work

- Evaluation of the seismic vulnerability of "Gaioleiro" buildings;
- Analyses of global and local behaviour;
- Definition of fragility curves.

Outline

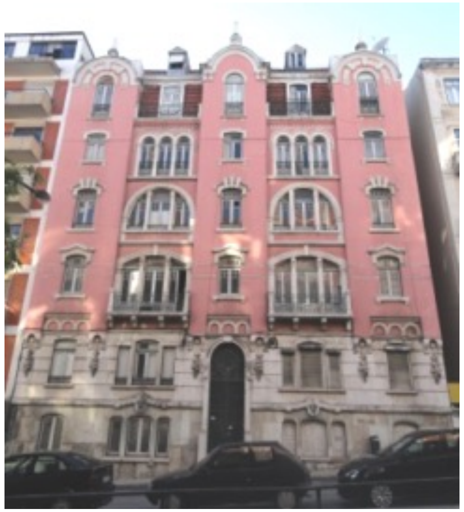
- The “gaioleiro” buildings
- Epistemic uncertainties
- Aleatory uncertainties
- Non-linear static analyses
- Definition of limit states
- Seismic performance-based assessment
- Derivation of numerical fragility curves
- Final comments

The “gaioleiro” buildings

- Buildings with 4 to 7 storeys high
- External walls: rubble limestone masonry and air lime mortar
- Internal walls: solid or hollow brick masonry and air lime mortar
- Floors: timber beams placed perpendicular to the main façade walls

Type I

Type II



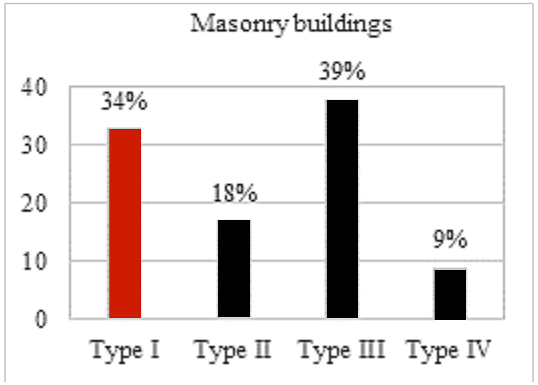
Type III

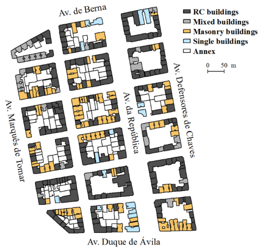
Type IV

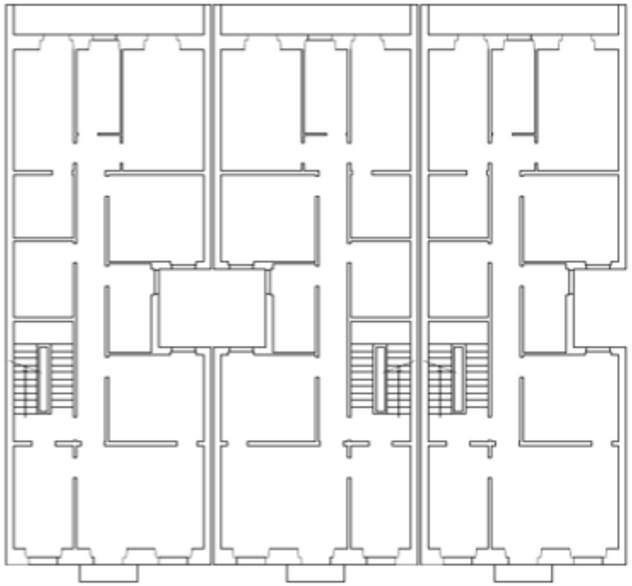
Simões, A. G.; Appleton, J. G.; Bento, R.; Caldas, J. V.; Lourenço, P. B.; Lagomarsino, S. (2016). Architectural and structural characteristics of masonry buildings on the transition between the 19th and 20th centuries in Lisbon, Portugal. Int J Archit Herit 11(4), pp. 457-474.

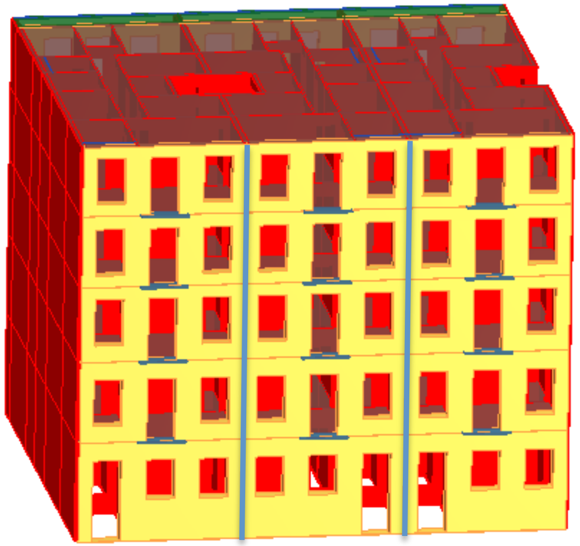
The “gaioleiro” buildings

- Building type I: asymmetric structure.
- Model with 3 buildings to analyse different boundary conditions.
- Numerical model defined in Tremuri Program according to the equivalent frame model approach.

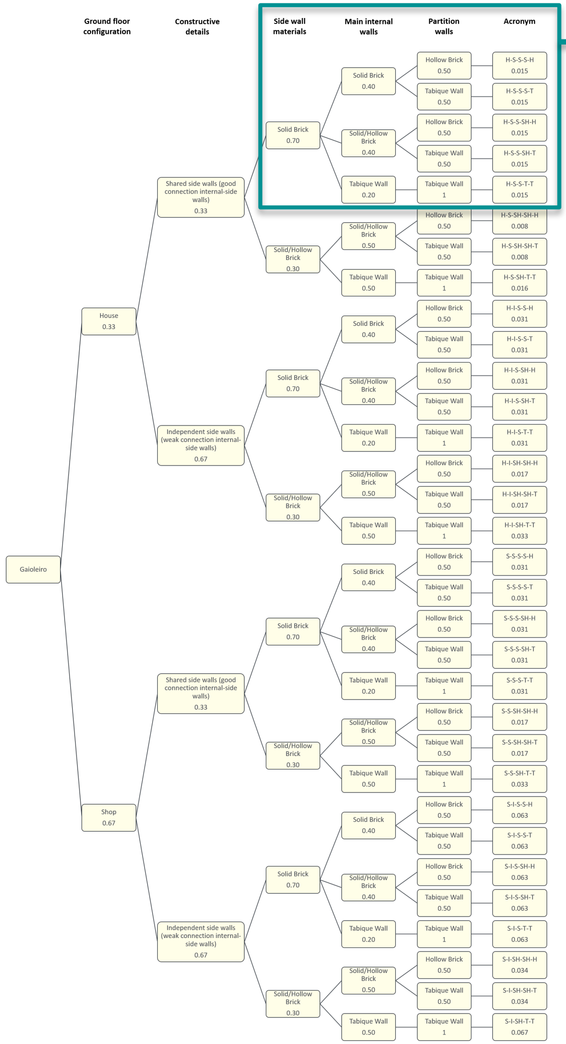




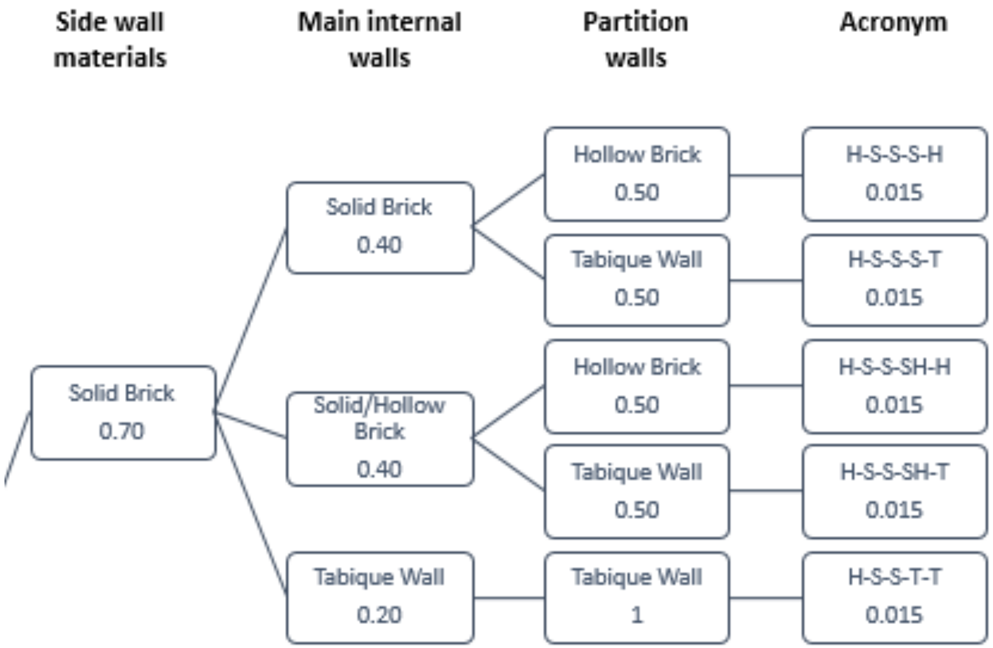




Epistemic uncertainties



32 models



- Ground floor configuration: housing vs. shopping
- Constructive details: shared vs. independent side walls
- Side wall materials: solid brick vs. hollow brick masonry
- Main internal walls: solid brick vs. hollow brick vs. timber
- Partition walls: hollow brick vs. timber (“tabique”)

Aleatory uncertainties

- Masonry properties (E, G, f_c, τ_0) determined with the Bayes Theorem.
- Modelling of masonry elements: multilinear constitutive law (K, δ and β).
- Modelling of spandrels with brick arch on the façade walls.
- Timber (“tabique”) wall properties from experimental results.
- Stiffness of timber floors (G) – NZSEE code.
- Connections between walls (A and I of link beams).

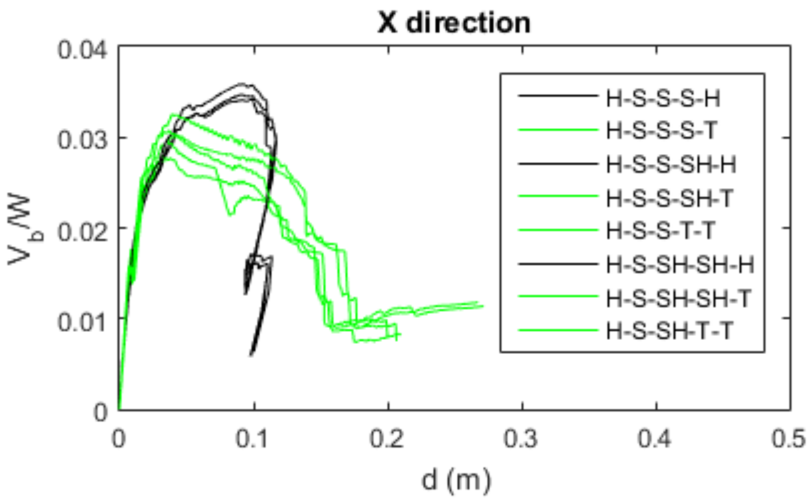
Type	Group	RV	Units	Median	Dispersion β
Rubble stone masonry	1	E	MPa	491.0	0.180
		G	MPa	163.7	0.180
		f_c	MPa	0.95	0.120
	2	τ_0	MPa	0.022	0.184
Solid brick masonry	3	E	MPa	560.4	0.160
		G	MPa	186.8	0.160
		f_c	MPa	1.07	0.113
	4	τ_0	MPa	0.074	0.214
	5	μ_{loc}	-	0.529	0.280
Hollow brick masonry	6	E	MPa	560.4	0.160
		G	MPa	186.8	0.160
		f_c	MPa	0.87	0.135
	7	τ_0	MPa	0.074	0.214
	8	μ_{loc}	-	0.529	0.280

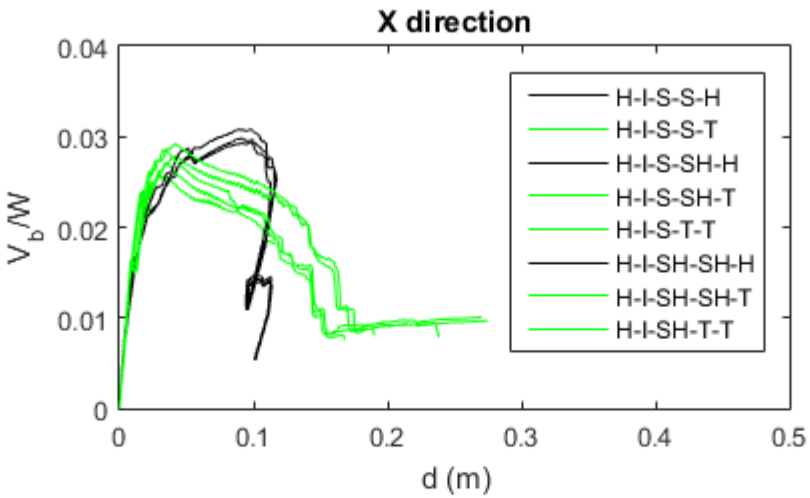
17 groups and 50 random variables

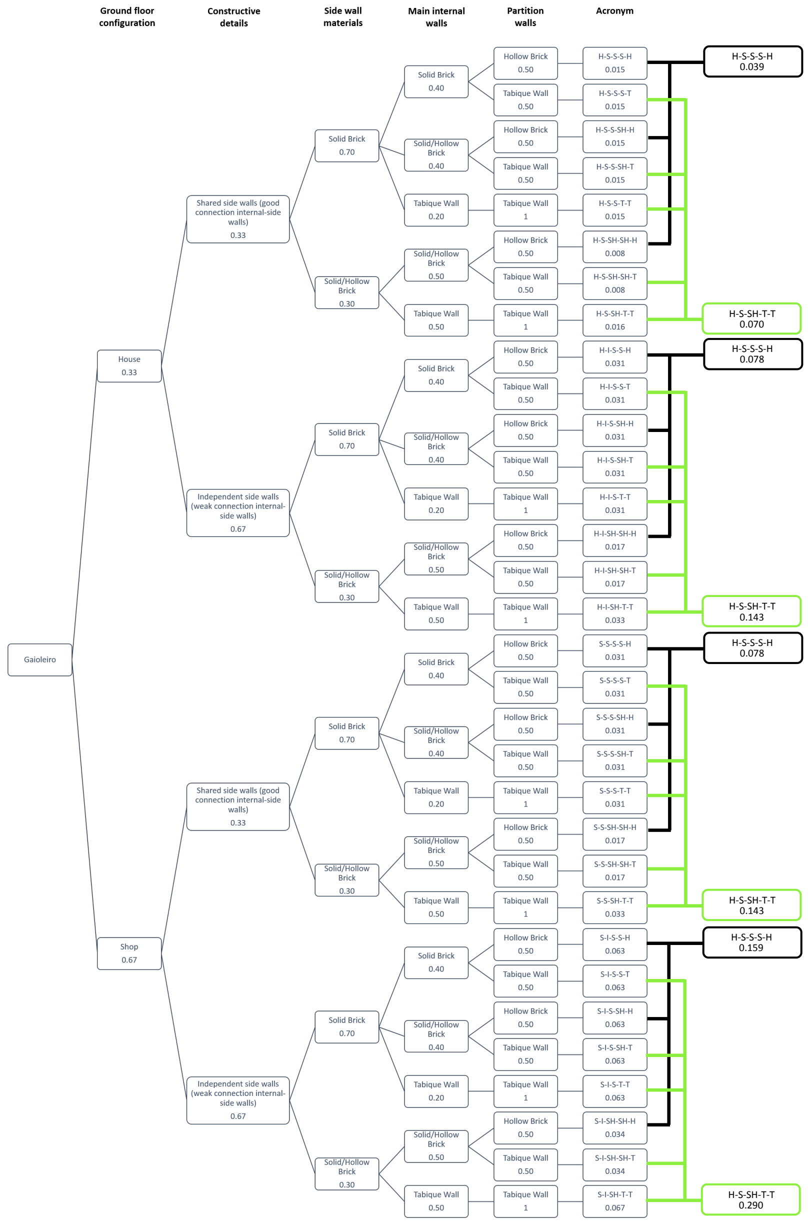
Lognormal and Beta distributions

1000 Monte Carlo simulations

Non-linear static analyses

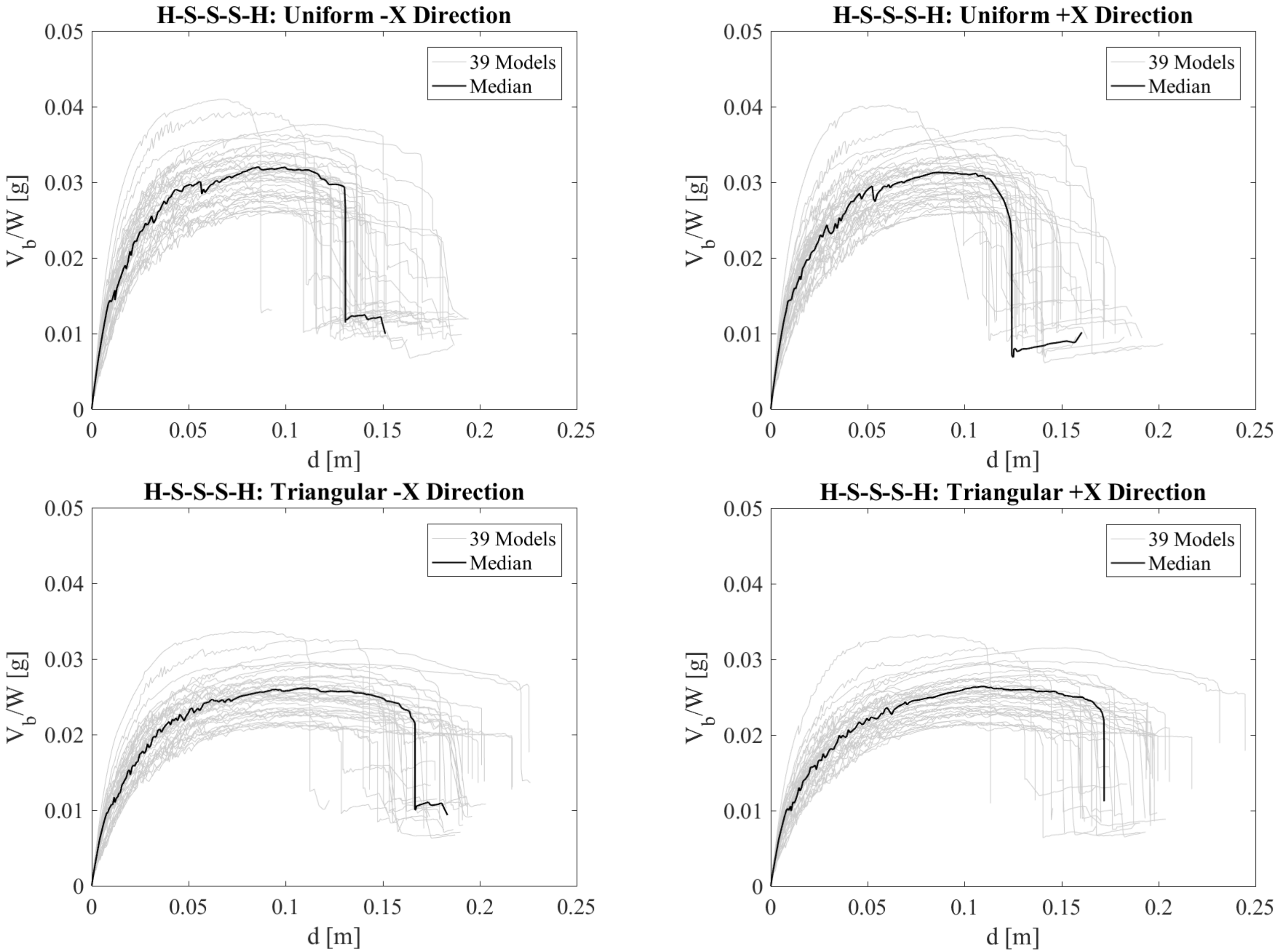




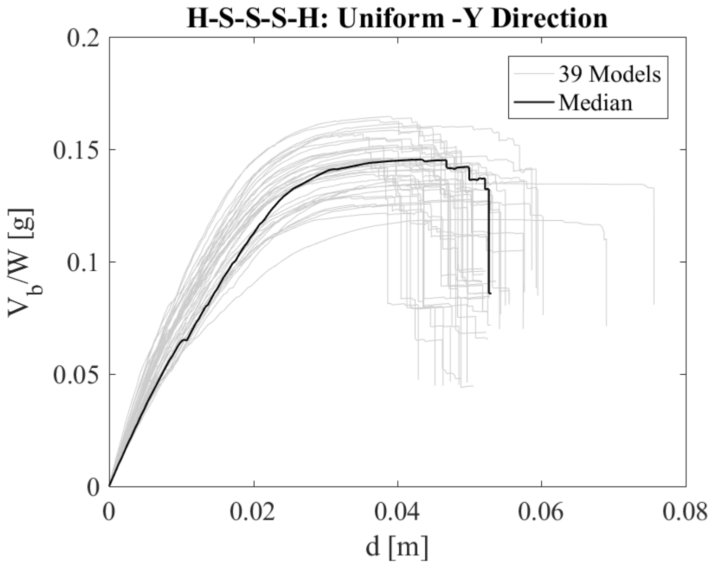


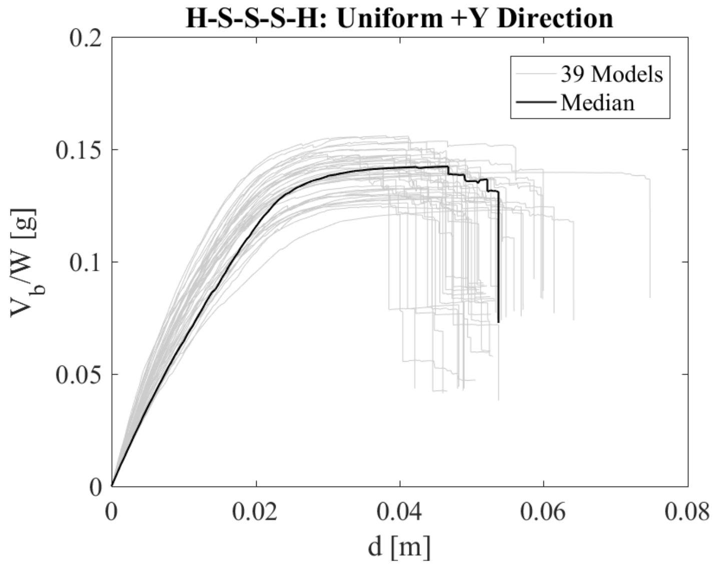
32 models → 8 models

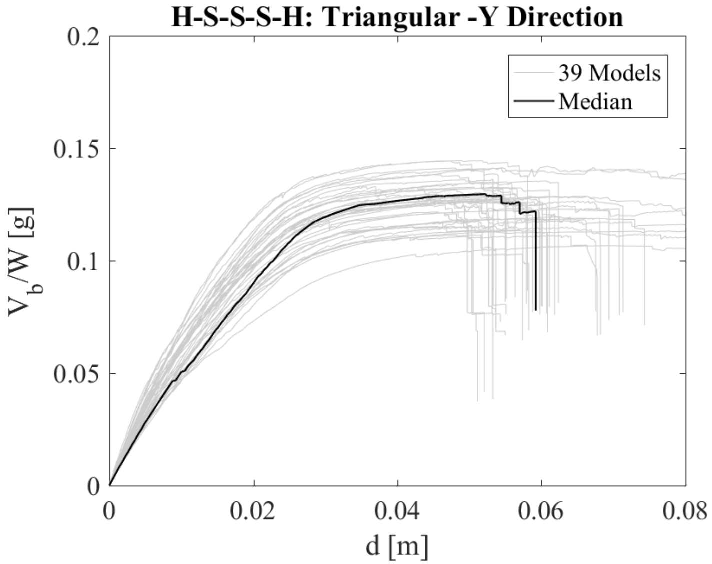
Non-linear static analyses

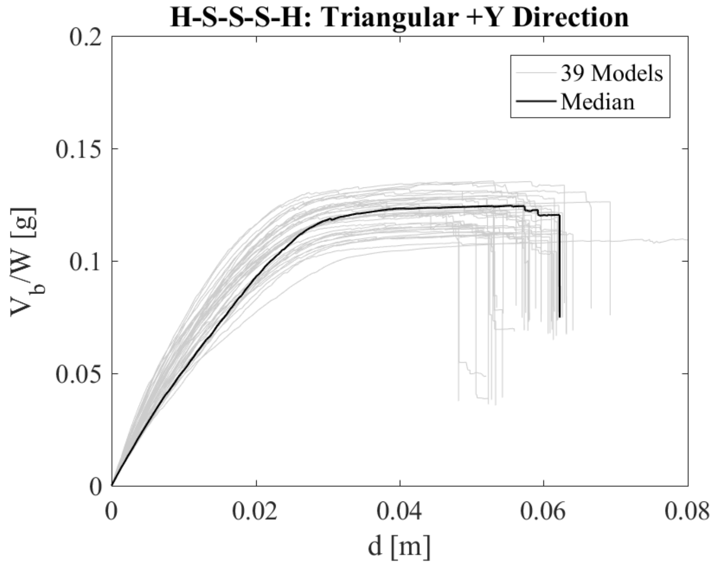


Non-linear static analyses

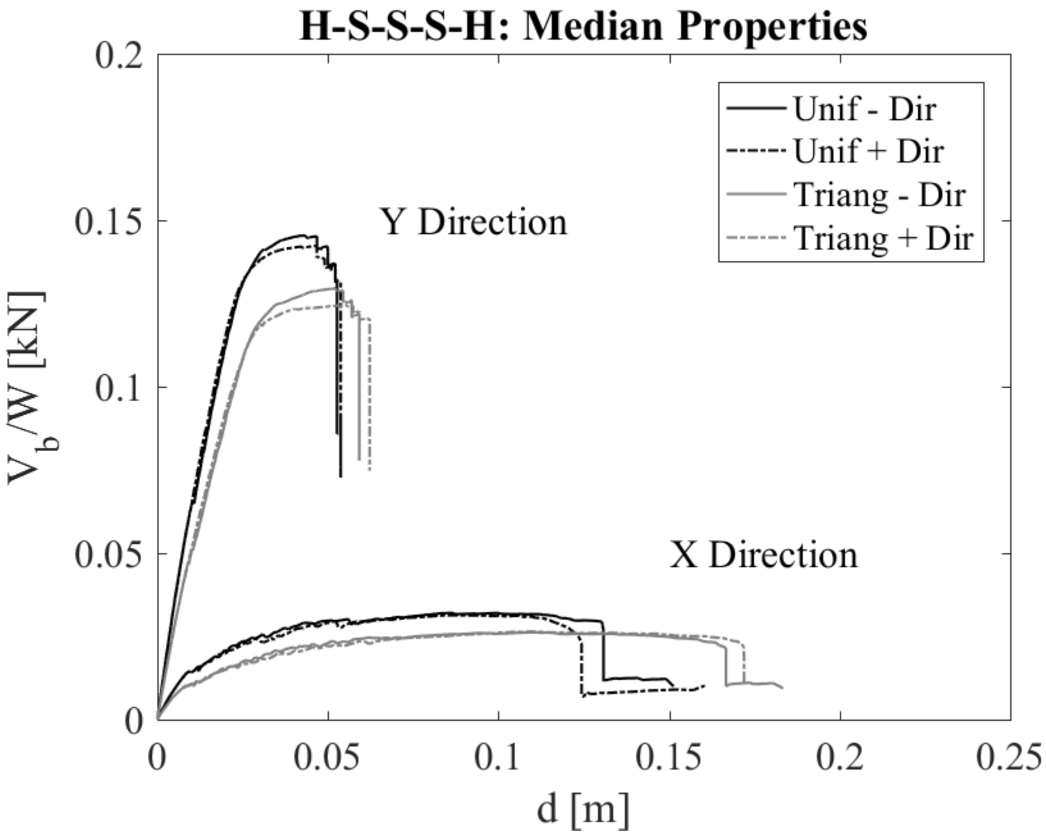


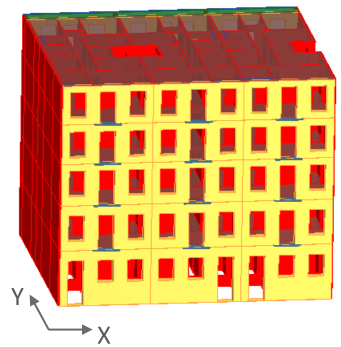






Non-linear static analyses





- Small variations between negative and positive directions.
- Higher initial stiffness and $V_{b,max}$ in the Y direction.
- Higher ultimate displacement in the X direction.

Seismic performance-based assessment

- Definition of Damage Levels (DLs) on the pushover curve based on a multiscale approach [1]:
    - Element (E) – cumulative damage rate of panels;
    - Macroelement (M) – cumulative damage rate of panels in each wall and each level;
    - Global (G) – percentage of the total base shear.

$$u_{DLk} = \min\left(u_{E,DLk};\ u_{M,DLk}; u_{G,DLk}\right) \quad k = 1, \ldots, 4$$

[1] Lagomarsino S., Cattari S. (2015) PERPETUATE guidelines for seismic performance-based assessment of cultural heritage masonry structures. Bull Earth Eng 13(1):13-47.

Seismic performance-based assessment

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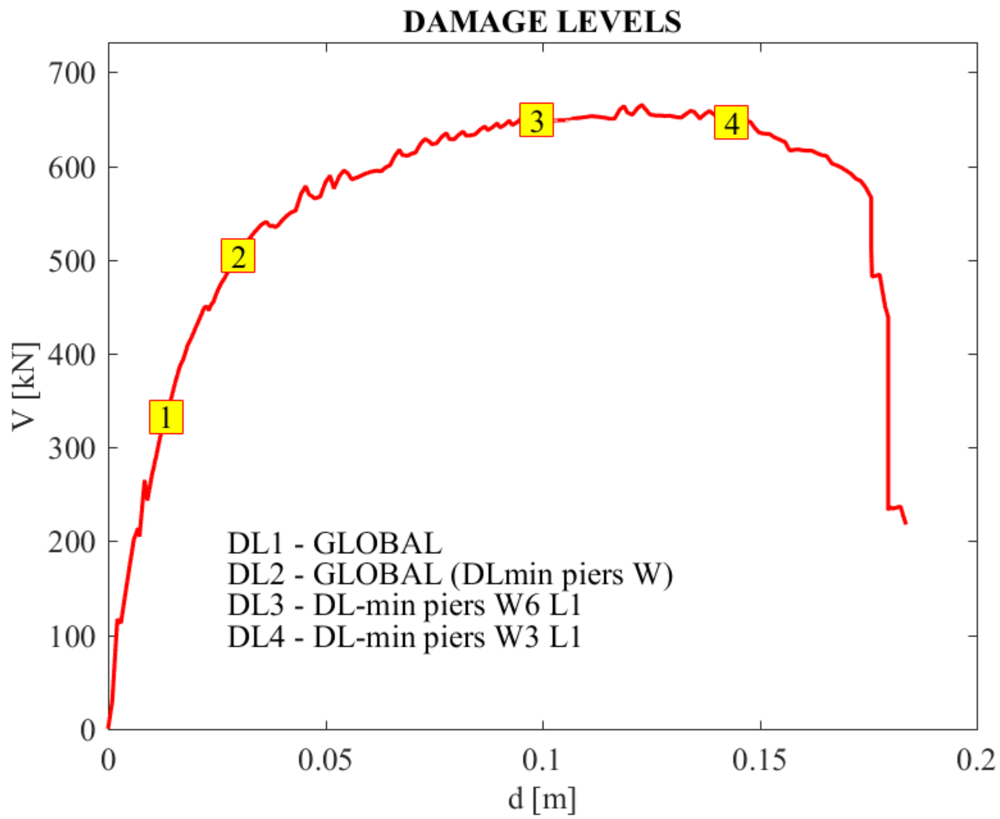

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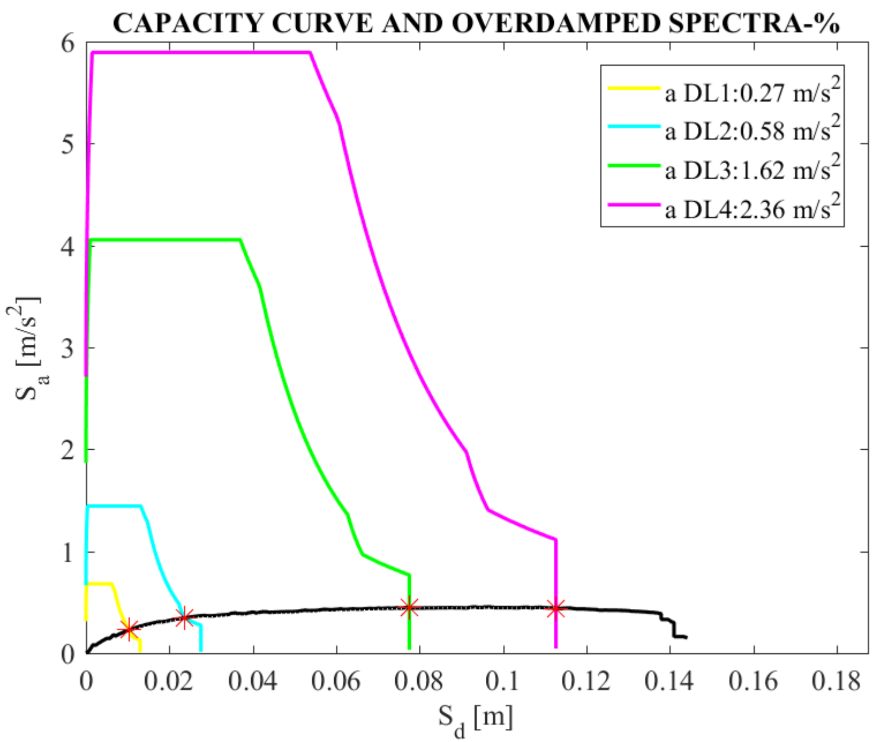
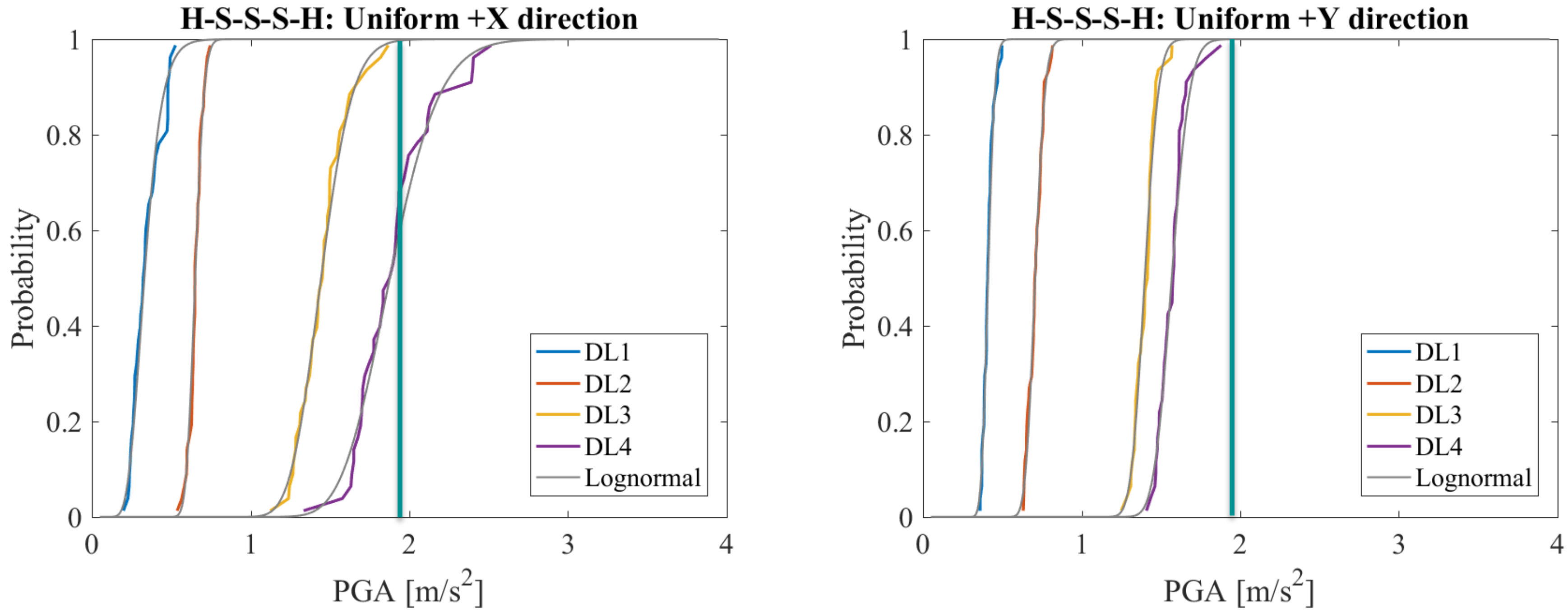
Seismic performance-based assessment

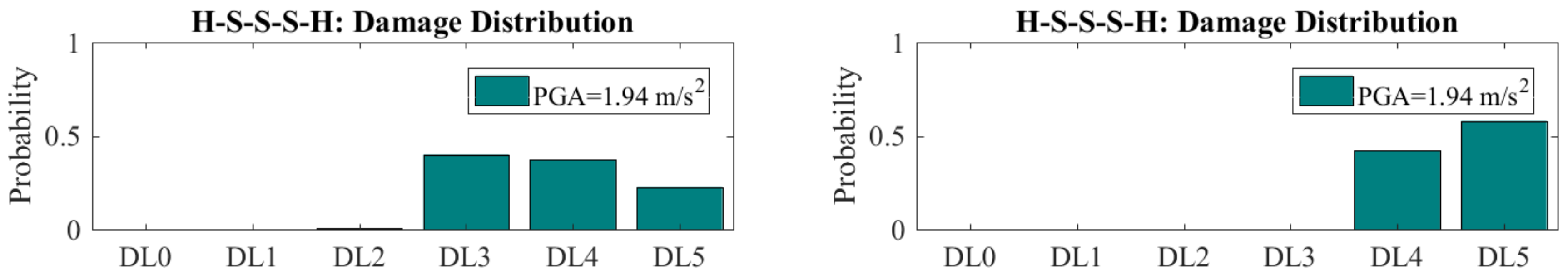
- Conversion of the pushover curve in an equivalent SDOF.
- Definition of the seismic demand based on the use of an overdamped spectra by adopting the Capacity Spectrum Method.
- Computation of the Intensity Measure (IM = PGA) compatible with the attainment of each DL.



Derivation of numerical fragility curves

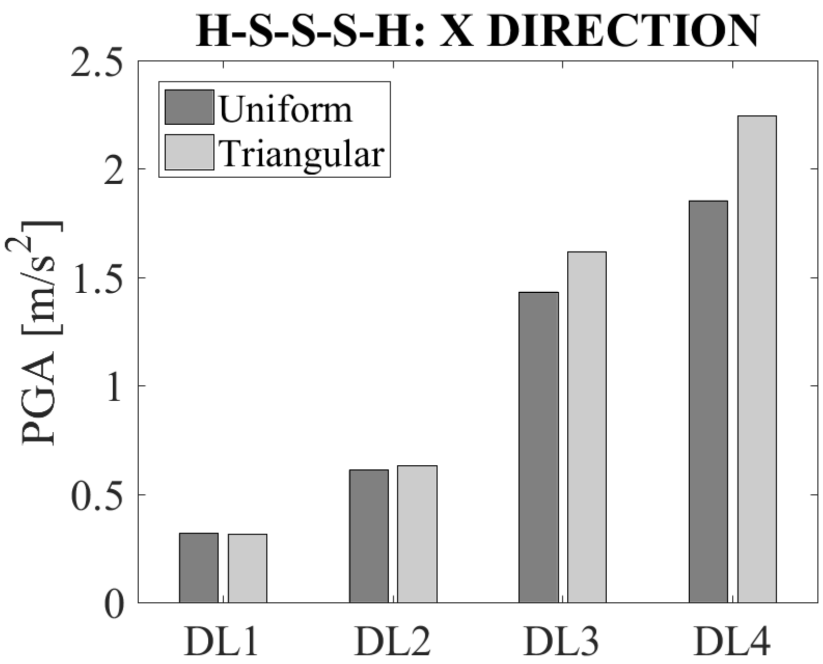
- Probability that a generic Damage Level (DL) is reached for a given IM.

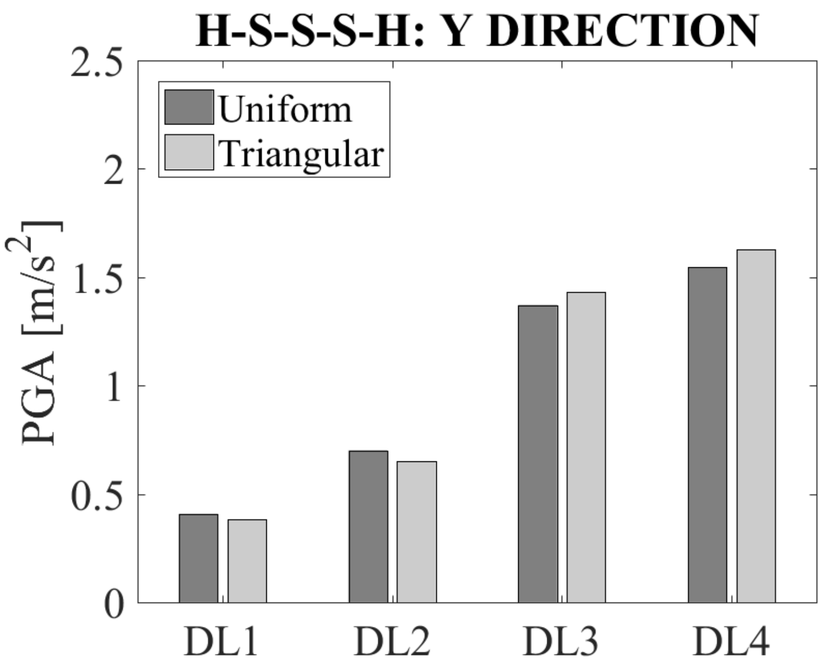




Derivation of numerical fragility curves

- Small variations of PGA between negative and positive directions (<9%). The minimum value is considered.

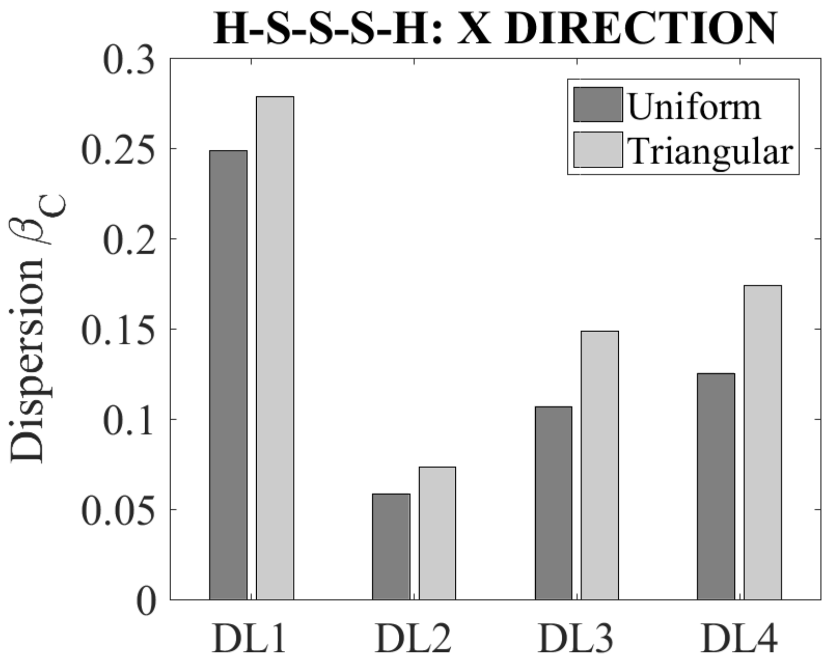


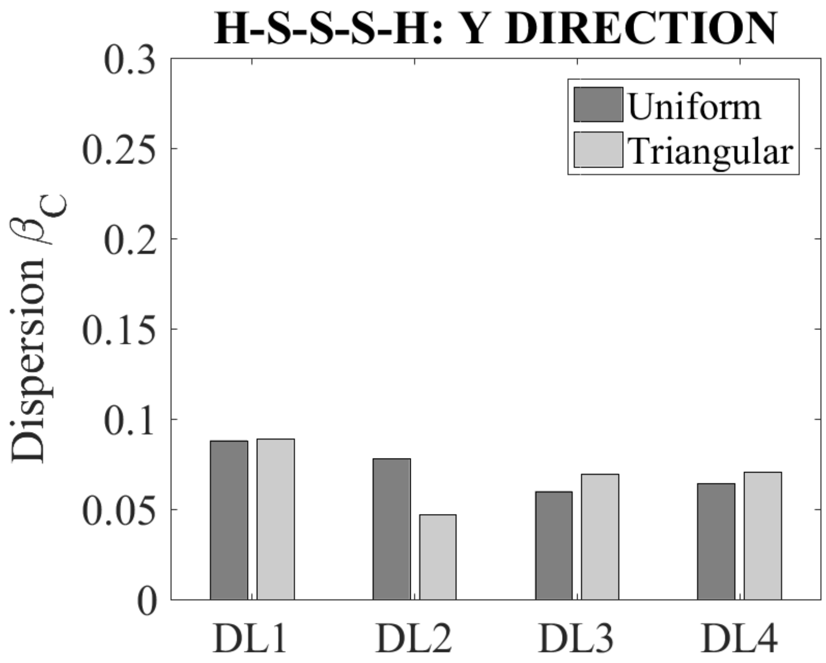


- Higher PGA for DL3 and DL4 with triangular load pattern.
- Higher PGA for DL3 and DL4 in the X direction.
- Seismic action type 1 is the most demanding seismic scenario.

Derivation of numerical fragility curves

- Uncertainty associated to the definition of the capacity curve (β_C).





- Uncertainty associated to the spectral shape of the seismic action (β_D).

$$\beta_T = \sqrt{\beta_C^2 + \beta_D^2}$$

Final comments

- Detailed assessment of the seismic vulnerability of URM buildings.
- Treatment of epistemic and aleatory uncertainties.
- Seismic performance-based assessment.
- Definition of numerical fragility curves.

Future work

- Derivation of the fragility curves for the 8 base models.
- Comparison with other fragility curves.
- Analysis of the local behaviour: out-of-plane mechanisms.

Thank you!