Seismic assessment of historical masonry construction including uncertainty

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Historical masonry structures

- Important part of the cultural heritage

- Low capacity against earthquakes

- Structural analysis involves uncertainty

- Consideration of uncertainty
  - ➢ Deterministic model
  - ➢ Uncertainty modelling
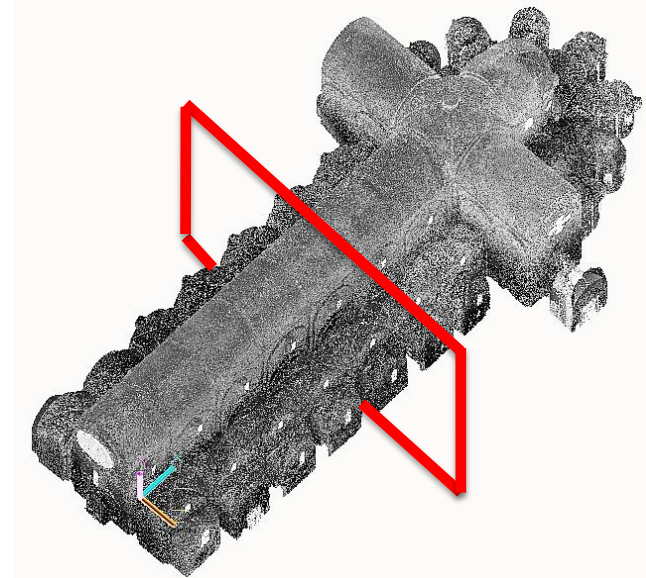 - ➢ Analysis

Case Study

- Church of the Santa Maria de Poblet monastery
  - ➢ UNESCO World Heritage Site
 - ➢ Presents damage and deformation in the main and the lateral aisles
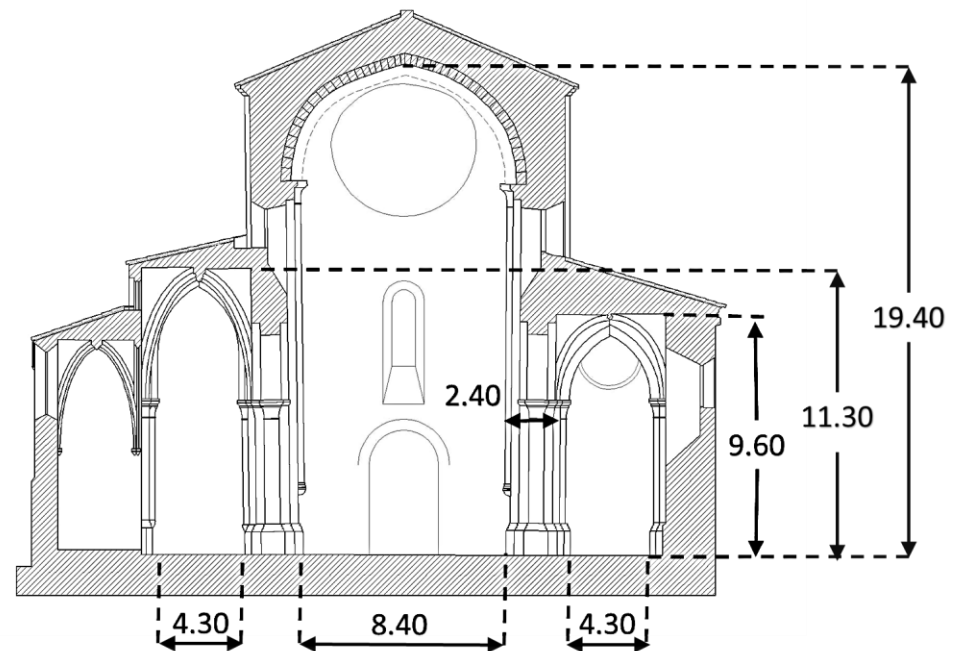
Deterministic model - structural analysis

- 2D FE model of the most vulnerable bay
  - ➢ Deformed geometry by laser scanner survey
  - ➢ Calibrated according to equivalent 3D model

- Non-linear static (pushover) analysis

- Material behaviour
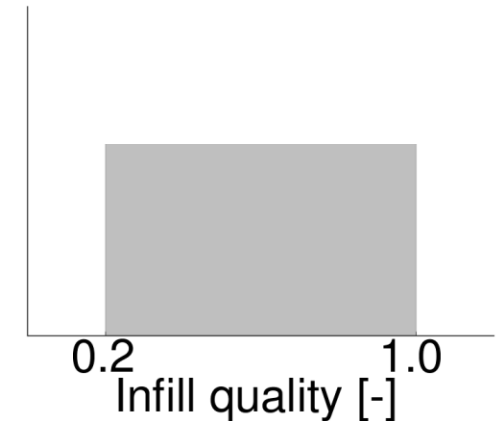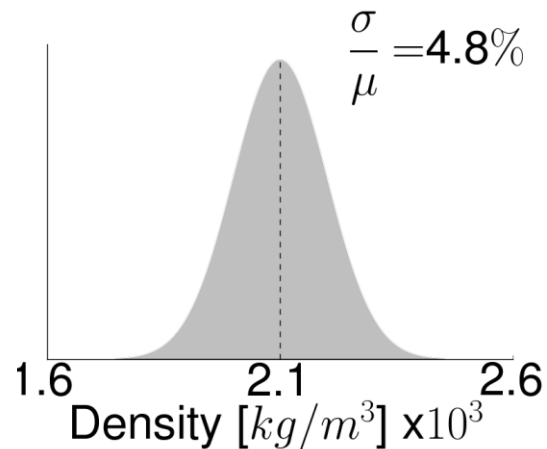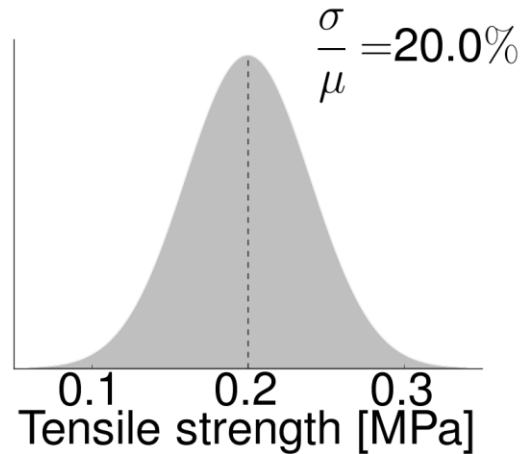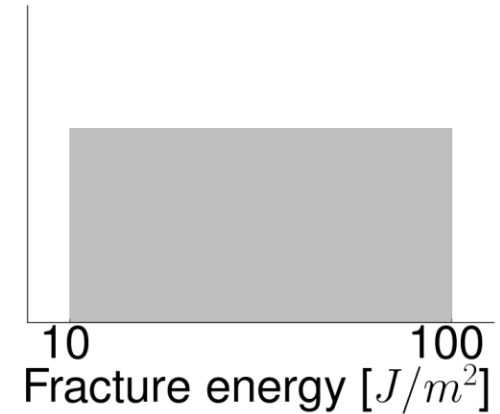 - ➢ Continuum damage model
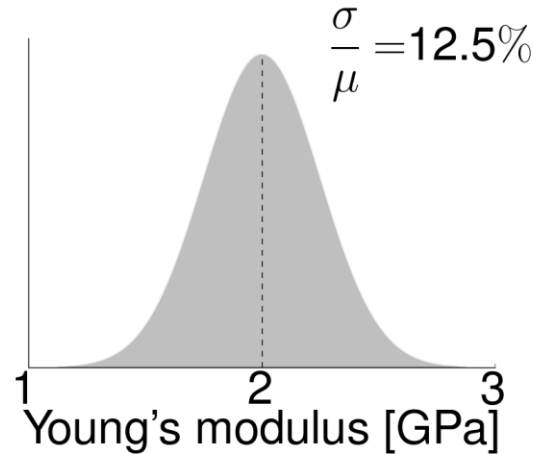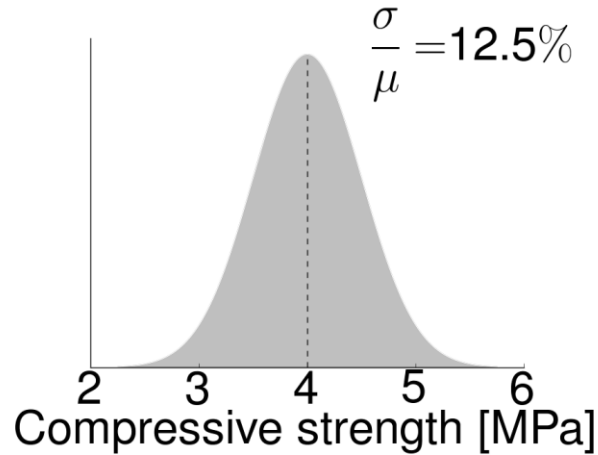 - ➢ Tensile crack tracking technique

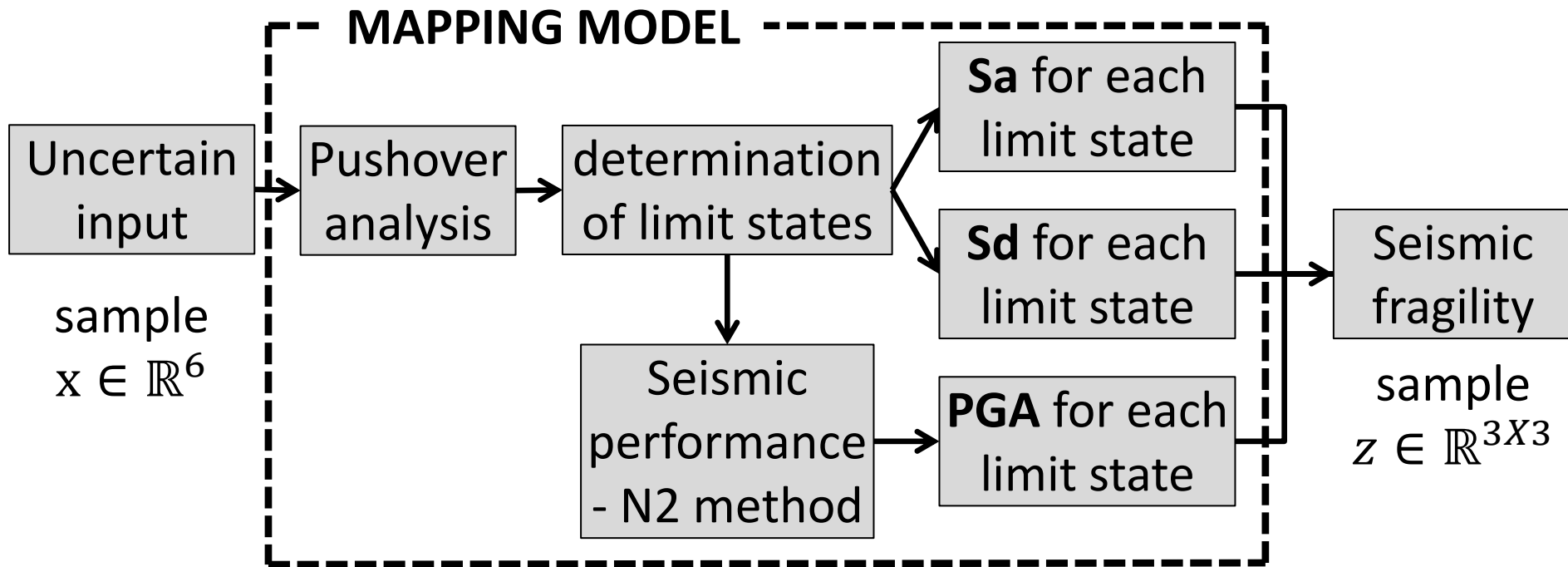# Deterministic model – seismic assessment
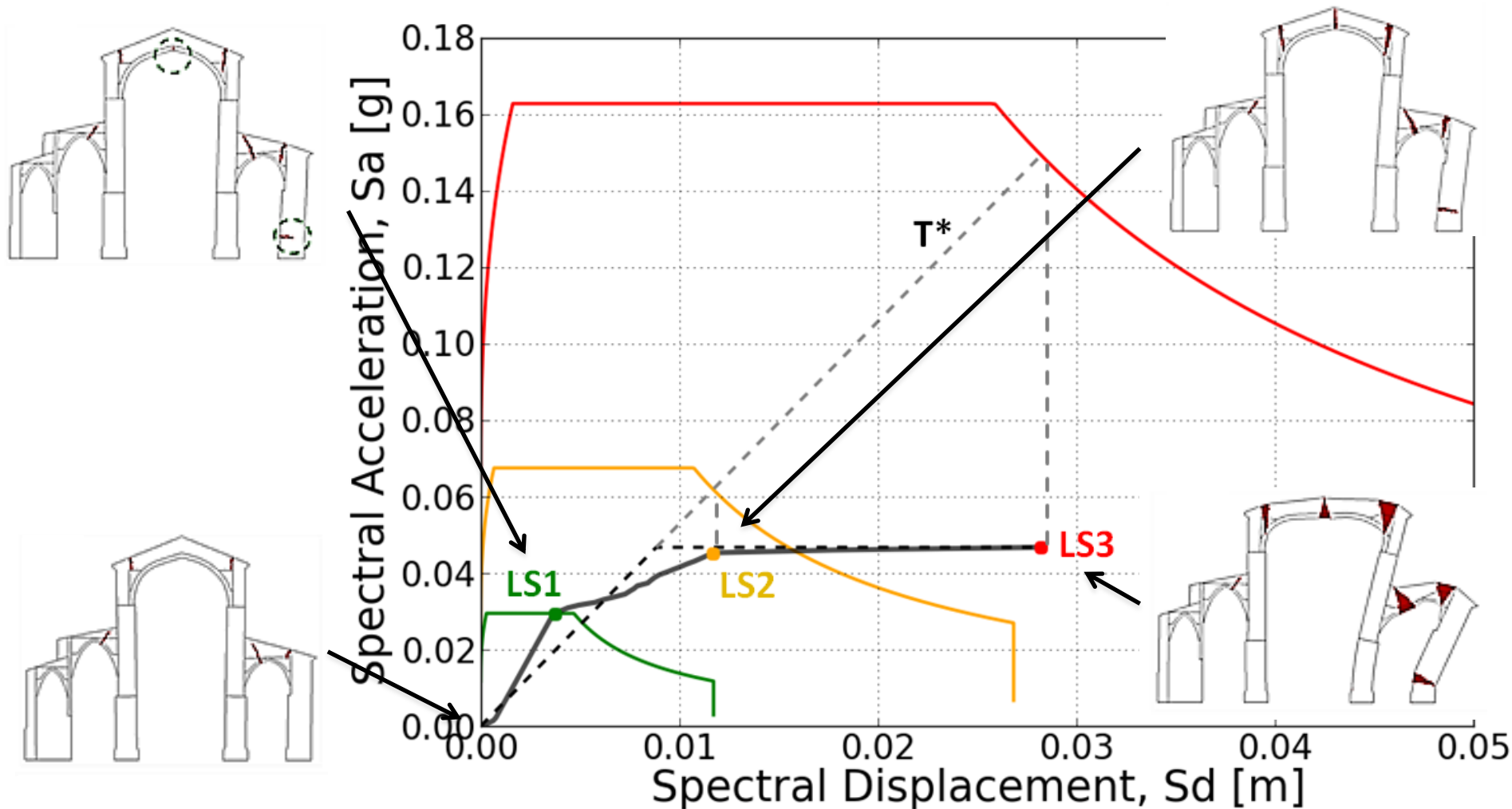
Uncertainty - material properties

• Random variables

Uncertainty - analysis

- Monte Carlo Simulation (MCS)
  - ➢ Latin Hypercube Sampling (LHS)

- Sample size N = 200

MAPPING MODEL

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Uncertain input  →  Pushover analysis  →  determination of limit states
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sample $x \in \mathbb{R}^6$

determination of limit states → **Sa** for each limit state

determination of limit states → **Sd** for each limit state

determination of limit states → Seismic performance - N2 method → **PGA** for each limit state

Sa for each limit state, **Sd** for each limit state, **PGA** for each limit state → Seismic fragility

sample $z \in \mathbb{R}^{3X3}$

Results – capacity curves
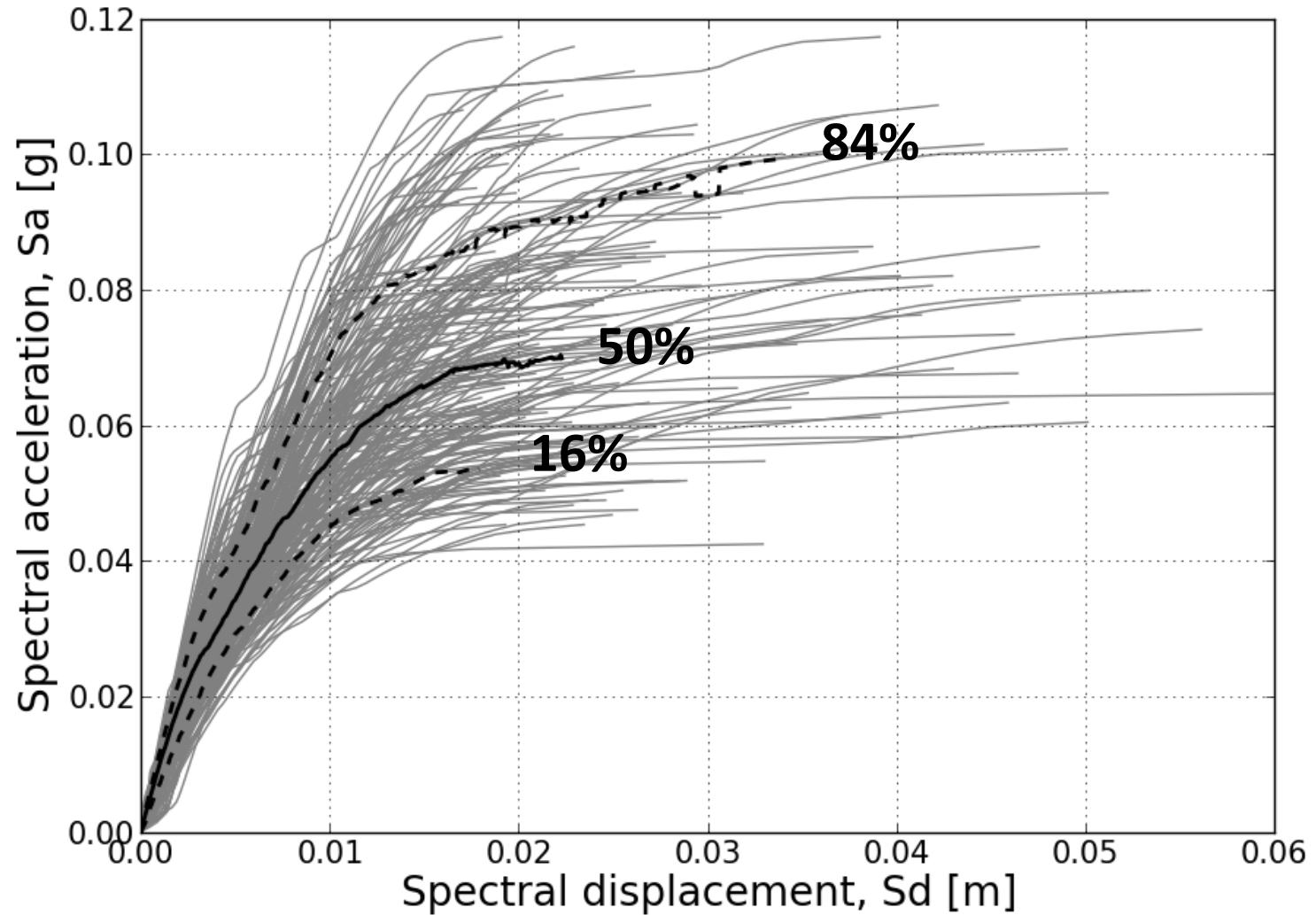
Results – capacity curves

Results – statistical properties
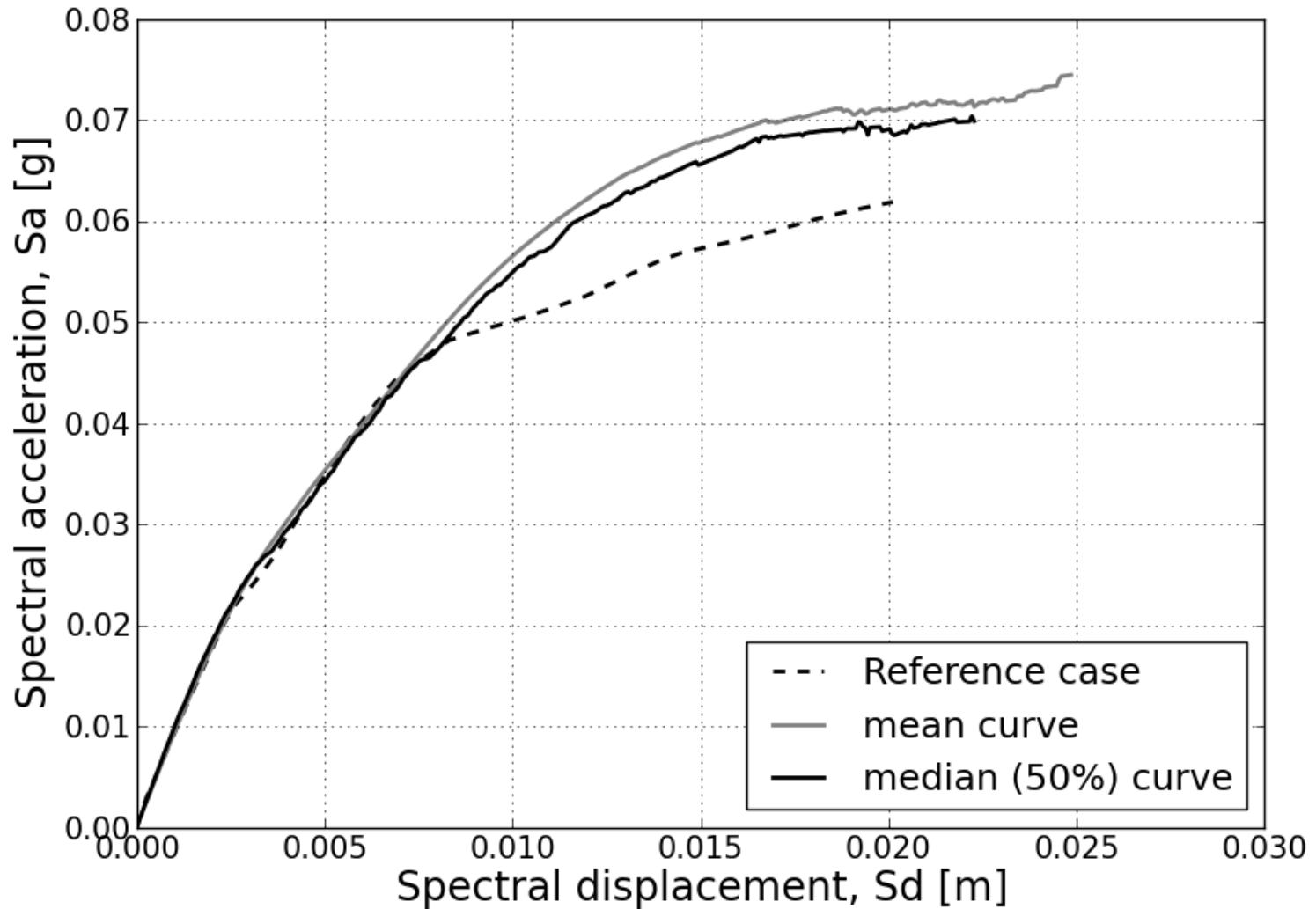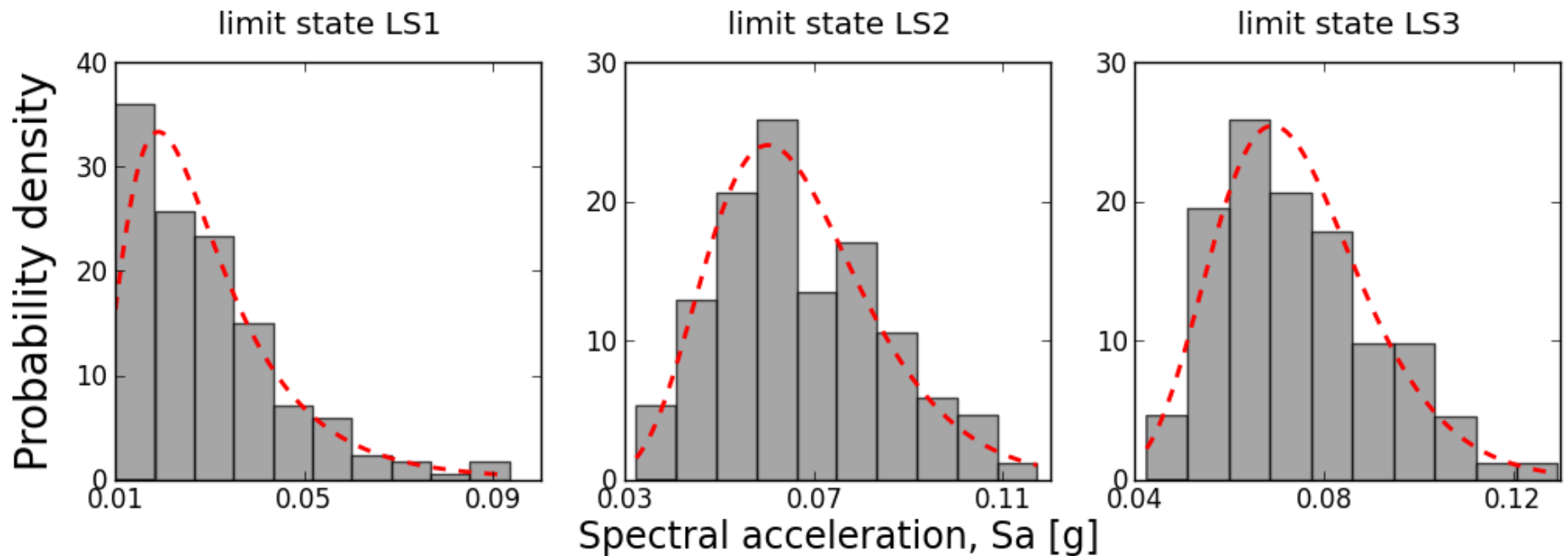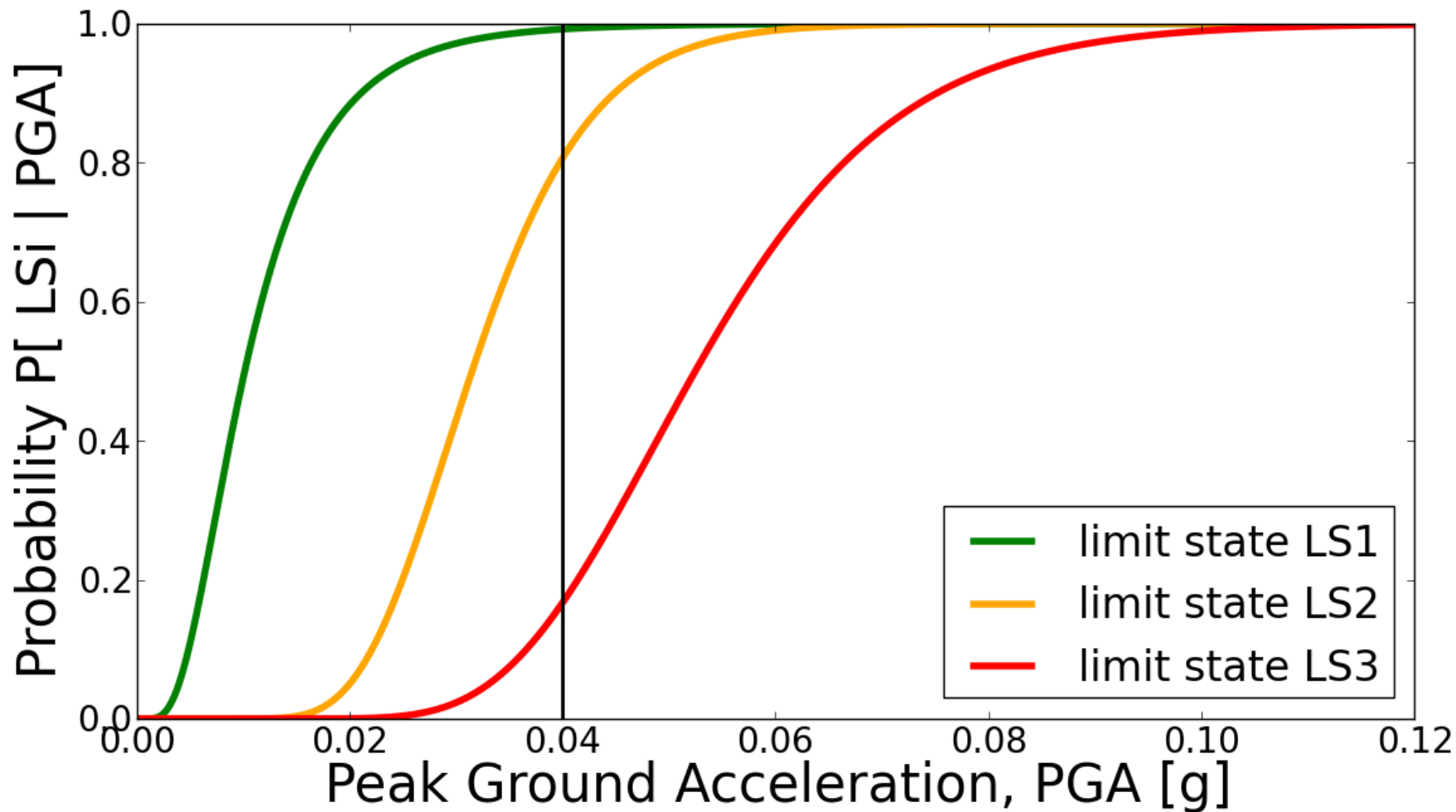
- Fragility – Log-normal cumulative distribution

- Central value – Geometric mean, ϑ

- Dispersion – logarithmic standard deviation, β

Results – fragility curves

Conclusions

- Adequate strategy for built cultural heritage prior to structural intervention

- Present damage attributed to past earthquakes

- Low probability of collapse

Thank you!

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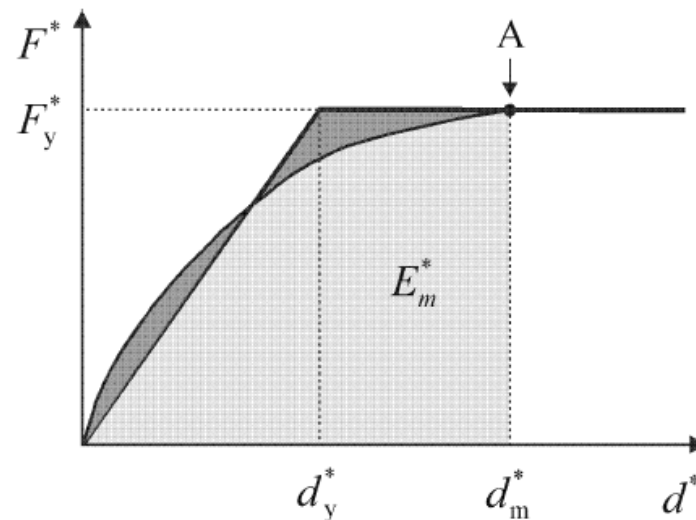
Appendix

- Determination of the equivalent SDOF system

$$m^* = \sum m_i \Phi_i \qquad F^* = \frac{F_b}{\Gamma} \qquad d^* = \frac{d_n}{\Gamma} \qquad \Gamma = \frac{m^*}{\sum m_i \Phi_i^2}$$

- Determination of the idealized bilinear curve

Localized crack tracking technique

Step 1: Crack origin

- ➢ Principal tensile stress exceeds strength
- ➢ Only at the boundaries of the model
- ➢ Minimum distance between two cracks

Step 2: Crack propagation

- ➢ To the principal stress direction of the element at the tip of the crack
- ➢ Stops when:
  - • Stress lower than strength
  - • Two cracks meet each other
  - • Reaches a boundary

Localized crack tracking technique

- ## **References:**

- Cervera, M., Pelà, L., Clemente, R., Roca, P. **"A crack-tracking technique for localized damage in quasi-brittle materials"** (2010) Engineering Fracture Mechanics, 77 (13), pp. 2431-2450.

- P. Roca, M. Cervera, L. Pelà, R. Clemente, M. Chiumenti. **"Continuum FE models for the analysis of a representative bay in Mallorca Cathedral"** (2013) Engineering Structures, 46, pp. 653-670.

- L. Pelà, M. Cervera, S. Oller and M. Chiumenti. **"A localized damage model for Orthotropic Materials"** (2014) Engineering Fracture Mechanics, 124–125, pp. 196–216