Site dependence and record selection schemes for building fragility and regional loss assessment

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OUTLINE

- Introduction
- Problem Definition
- Application of the method
- Results
- Concluding remarks

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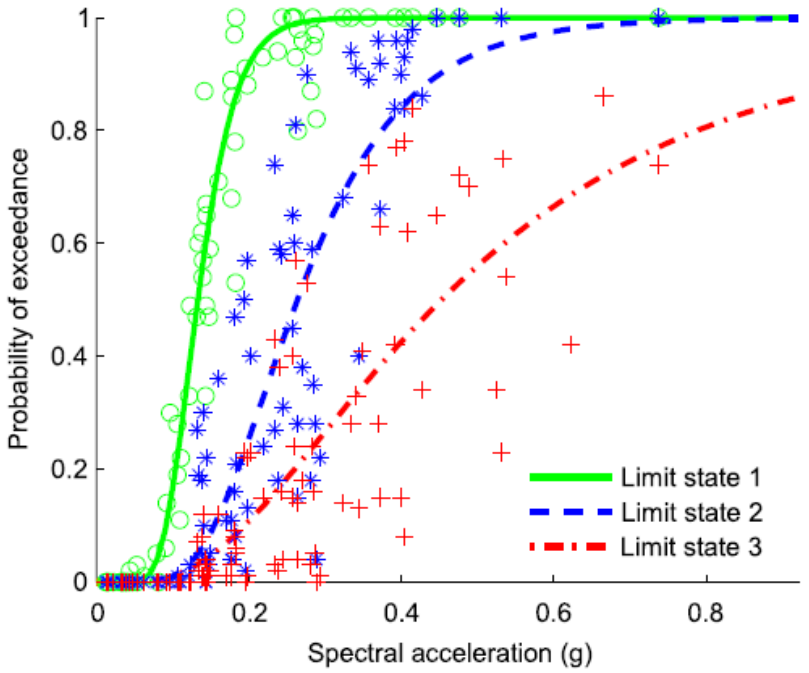
Introduction/Fragility Function

- What is a fragility function?
  - Shows the probability of exceedance of a limit state
  - Threshold of a EDP → usually MIDR
- What is it used for? → mainly in portfolio loss estimation
- How is it defined? → log normal, logarithmic mean and standard deviation

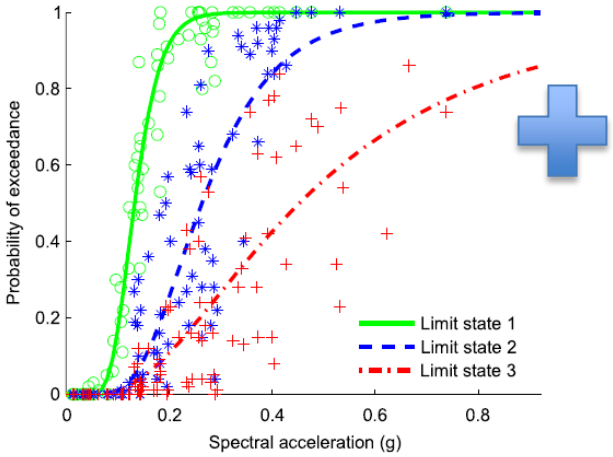
$$P(LS \mid IM = x) = \Phi\left(\frac{\ln(x/\theta)}{\beta}\right)$$



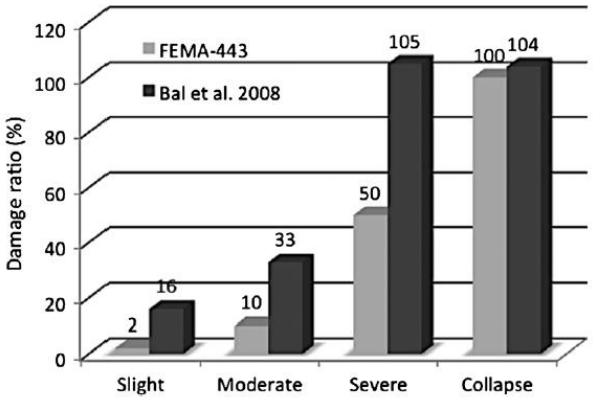
Introduction/Portfolio loss estimation

- How Fragility/vulnerability curves are obtained
  - Empirical → Best but lack of data
  - Analytical → most common (OUR FOCUS)
  - Engineering Judgement →
  - Hybrid → combination of two or all above

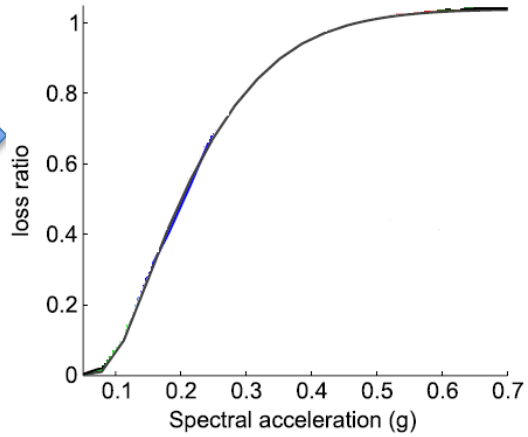
Fragility



Damage Function



Vulnerability Function



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Problem Definition/Analytical fragility curves

What is our concern here?

- Recent studies → building response is building and site dependent
- i.e. conditional spectrum & GCIM record selection
- Assume one building (class) at different sites → different seismicity
- Are fragilities site dependent too? (main question here)

What is usually done?

- One set of records → IDA → single fragility curve for all sites!

What is the most accurate approach? ("perfect" approach)

- Per building/per site → most accurate, large book keeping, time consuming.

Is there an alternative? → more accurate than IDA & less time consuming than the perfect approach

Problem Definition/fragility curves

Two alternatives defined here:

1- "multi-run" approach *(benchmark here)*

- Select records for each site → site dependent fragility for each
- Law of total variability → combine the multiple fragilities to single one
- Use one fragility curve in the procedure

2- "Single-run" approach

- Select one set of records to represent all sites
- Obtain single analytical fragility
- Use one fragility curve the procedure

Problem Definition/multi-run approach

- **"multi-run" approach**
- Law of total variability → combine the fragilities
- Need to consider weight for each site (Ps)

$$\mathrm{P}(LS \mid IM) = \sum_{s=1}^{n} P_s \cdot \mathrm{P}(LS \mid IM, s)$$

Logarithmic mean

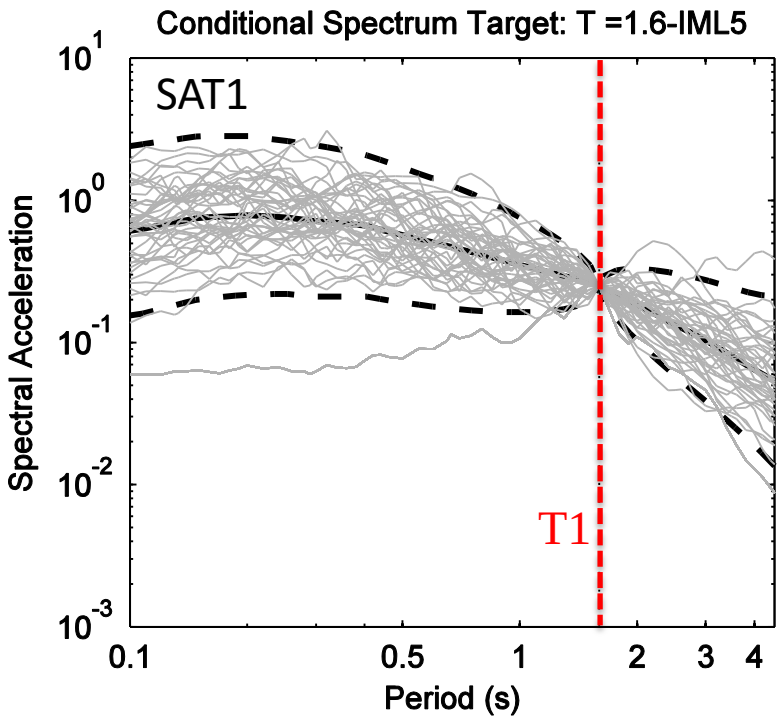
$$\theta_{tot} = \exp\left[\sum_{s=1}^{n} P_s \cdot \ln(\theta_{IM,s})\right]$$

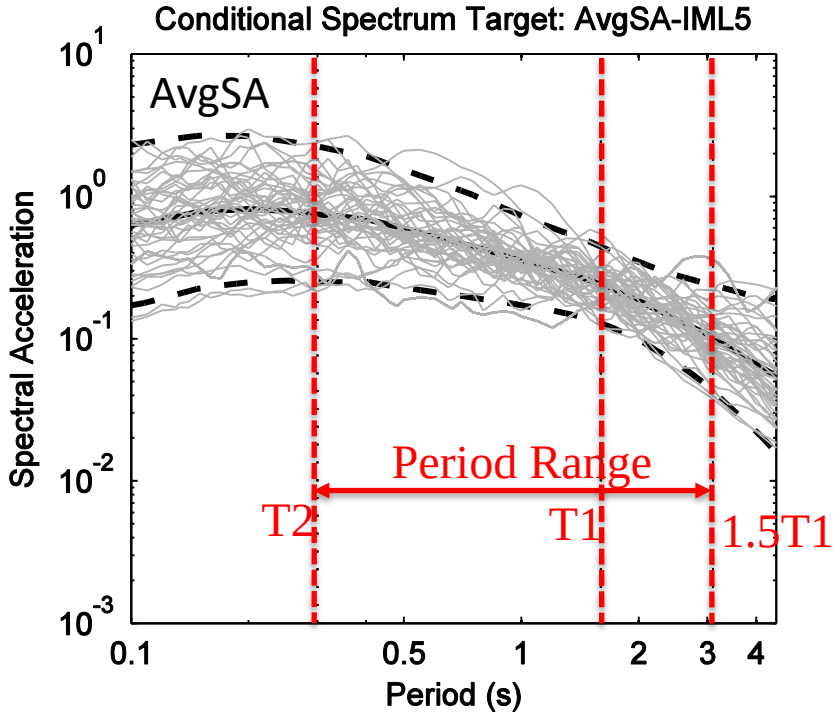
Logarithmic dispersion

$$\beta_{tot} = \sqrt{\sum_{s=1}^{n} P_s \cdot \left[\beta^2_{\ln IM,s} + \left(\ln\left[\frac{\theta_{tot}}{\theta_{IM,s}}\right]\right)^2\right]}$$

Problem Definition/single-run approach

- **"single-run" approach**
- Conditional spectra (CS) -based record selection (Jayaram *et al.*, 2012)
- Considers both mean and variance in the target spectrum
- CS conditioned on *AvgSA* → CS(*AvgSA*), Kohrangi *et al.* (2016)





Problem Definition/single-run approach

- **"single-run" approach**

- Exact method of CS, Lin *et al.* (2012) → law of total variability
- Variability for: For *causal events*, *GMPE*s → We extended to *site*

$$\mu_{\ln SAT_i|\ln IM*} = \sum_s \sum_j \sum_k p_{s,j,k} \cdot \mu_{\ln SAT_i,s,j,k|\ln IM*}$$

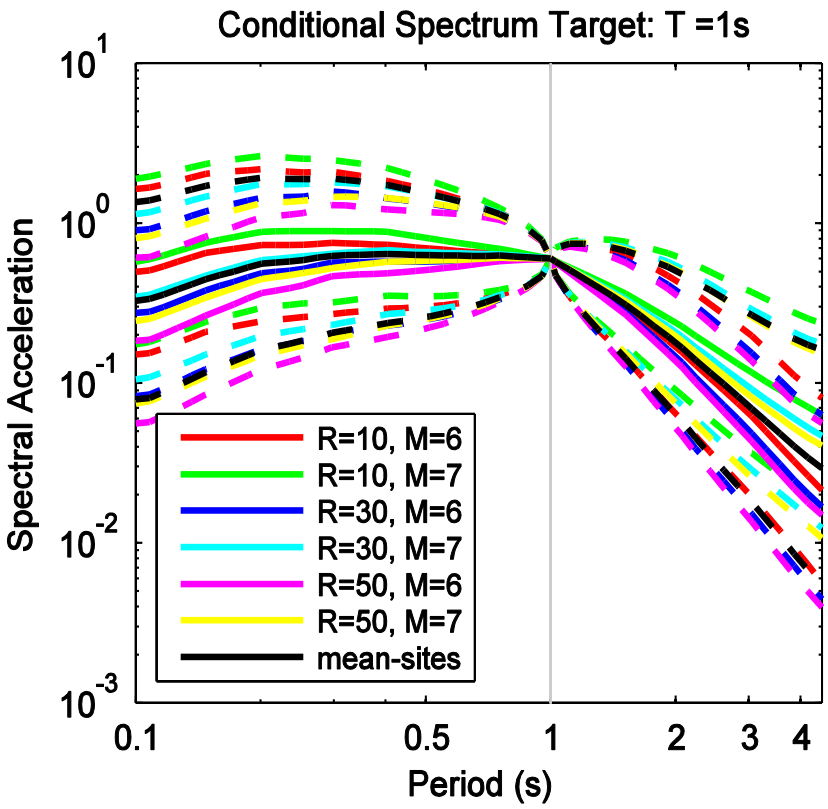
$$\sigma_{\ln SAT_i|\ln IM*} = \sqrt{\sum_s \sum_j \sum_k p_{s,j,k} \cdot \left[\sigma^2_{\ln SAT_i,s,j,k|\ln IM*} + \left(\mu_{\ln SAT_i,s,j,k|\ln SAT*} - \mu_{\ln SAT_i|\ln IM*} \right)^2 \right]}$$

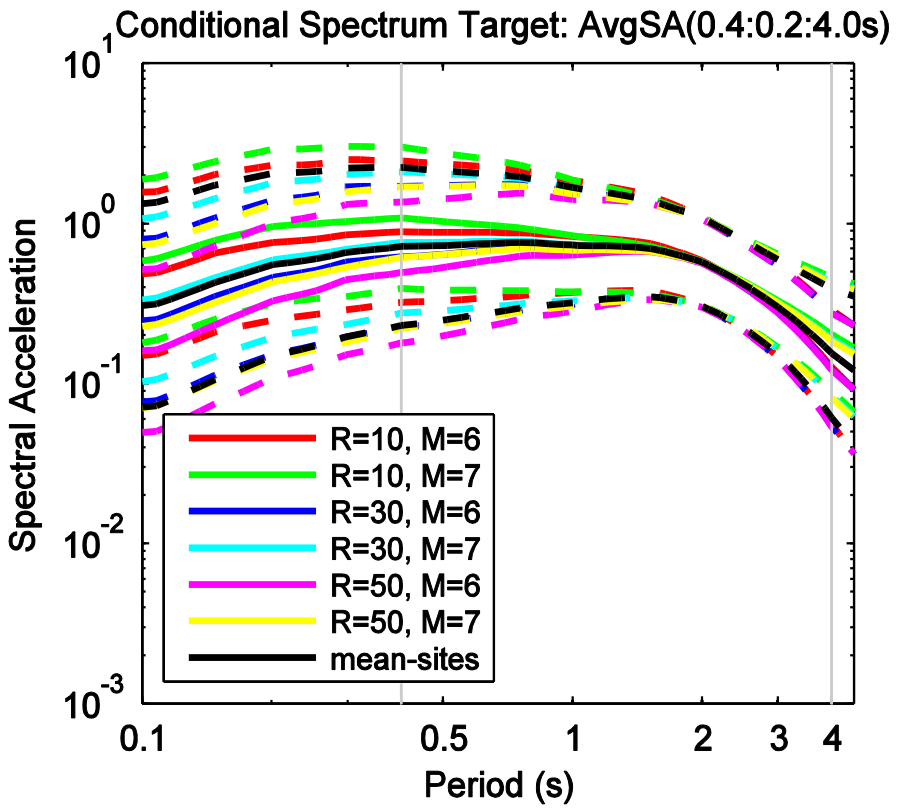
Problem Definition/single-run approach

EXAMPLE

- **Six sites**
- **Black line: mean of all**

Site #	S1	S2	S3	S4	S5	S6
R(km)	10	10	30	30	50	50
Mw	6	7	6	7	6	7





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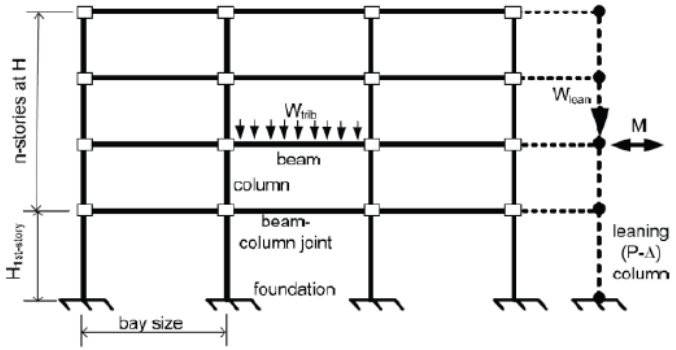
Application of the method/Building Examples

Description:

- Plan-symmetric moment-resisting frames
- 4-, 7-, 12- & 20-story buildings
- Post-1980 seismic design provisions regions (NEHRP site class D)

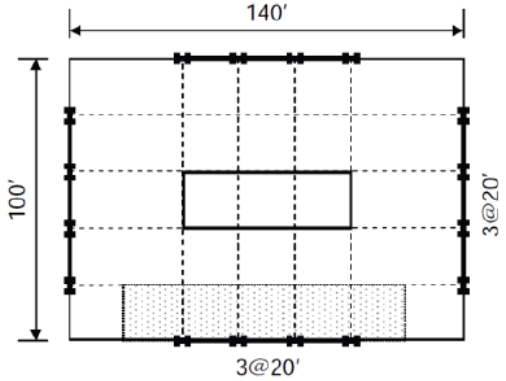
Modeling assumptions:

- OpenSees
- 2D centerline idealization
- lumped-plasticity elements
- P-Δ effects



(a)

(b)

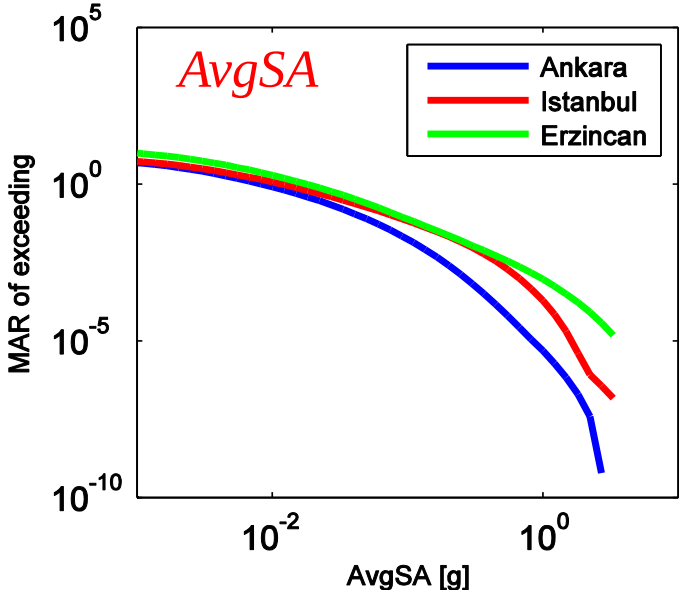


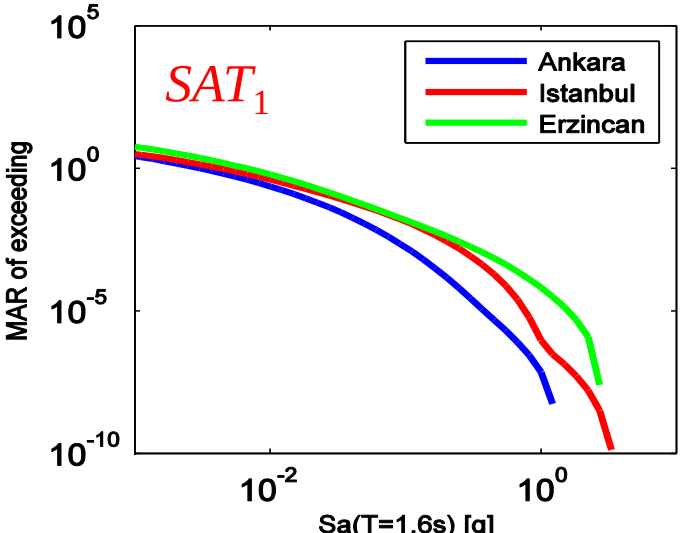
(c)

Application of the method/Selected site– Hazard analysis

Hazard analysis/Disaggregation

- OpenQuake
- SHARE Project, hazard source model
- GMPE proposed by **Boore and Atkinson (2008)**
- **Ankara, Erzincan and Istanbul**

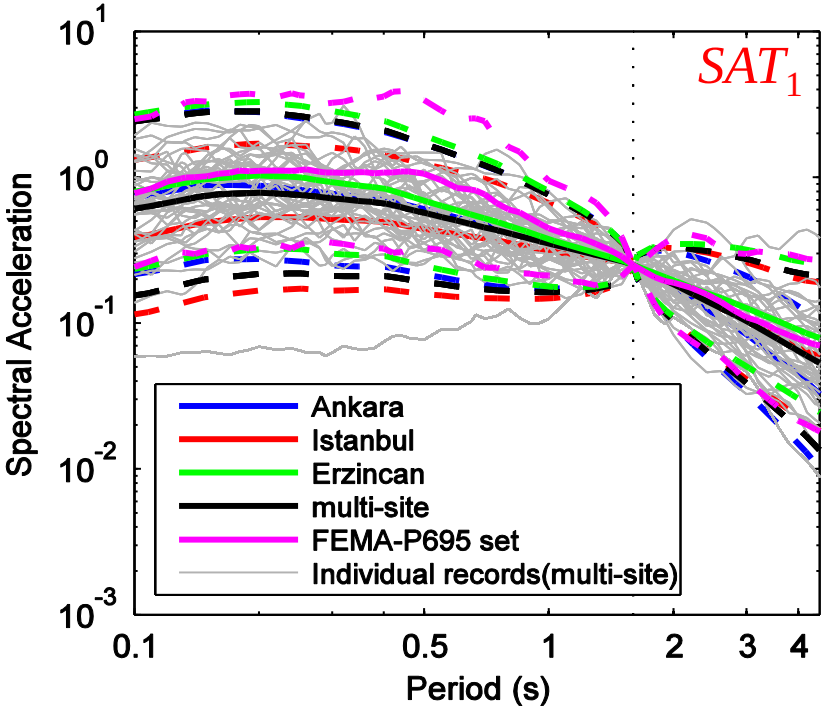


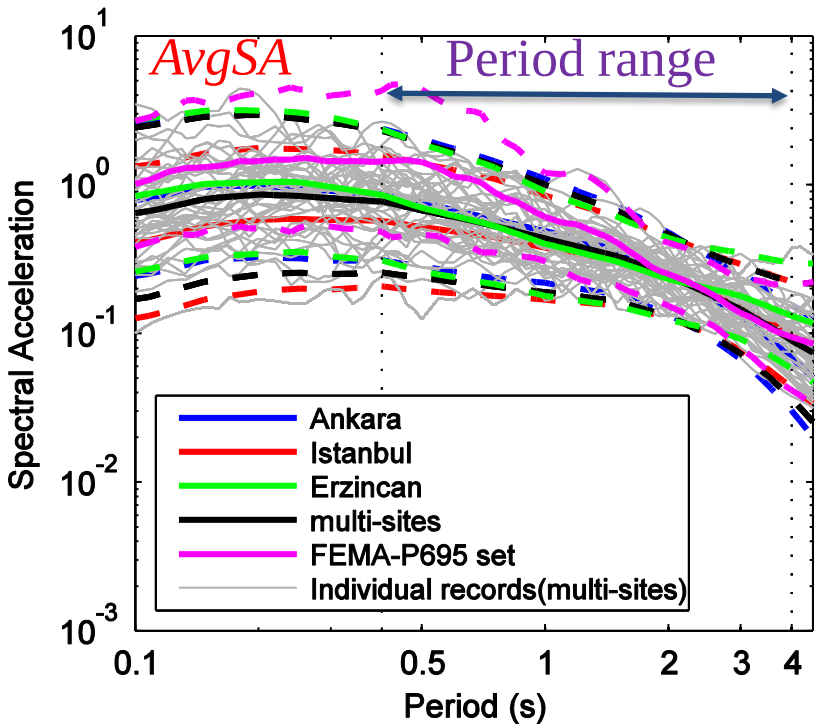


Application of the method/Record selection: Portfolio

SO WHAT IS THE SOLUTION?

1. Different site-specific fragilities (direct method) → multiple record set, multiple fragilities
2. Combine site-specific fragilities (mean-frag) → multiple record set, one fragility
3. Incorporating multiple-sites in one record set (mean-sites)→ one record set, one fragility



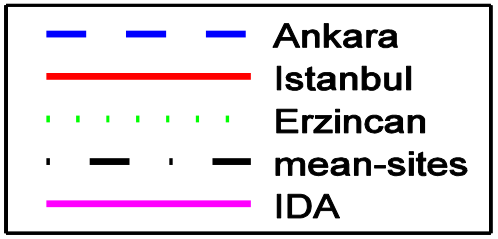


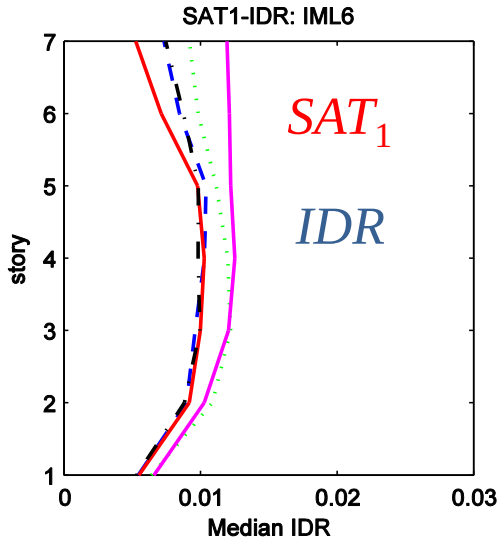
RESULTS/Local level

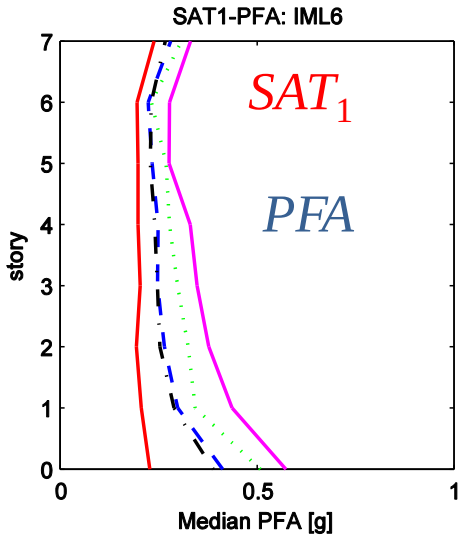
Building response:

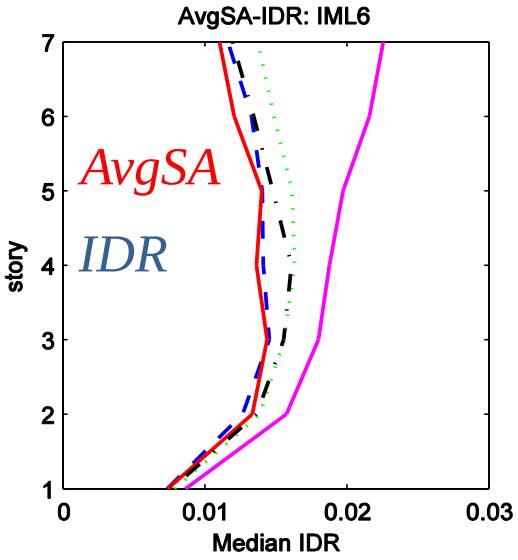
- Records:
  CS(*AvgSA*), CS(SAT_1) & IDA
- Different record sets for each site
- Median IDR and PFA along the height
- Building response is a function of the seismicity of the site.

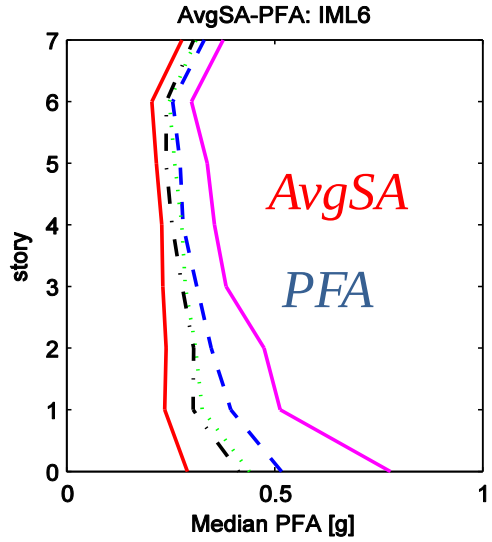
IM=0.35g







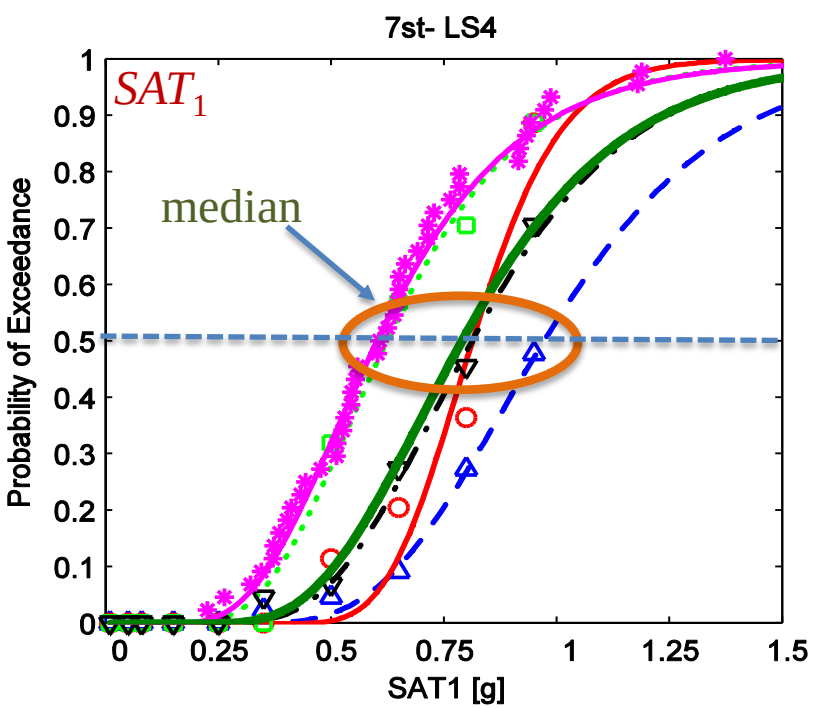


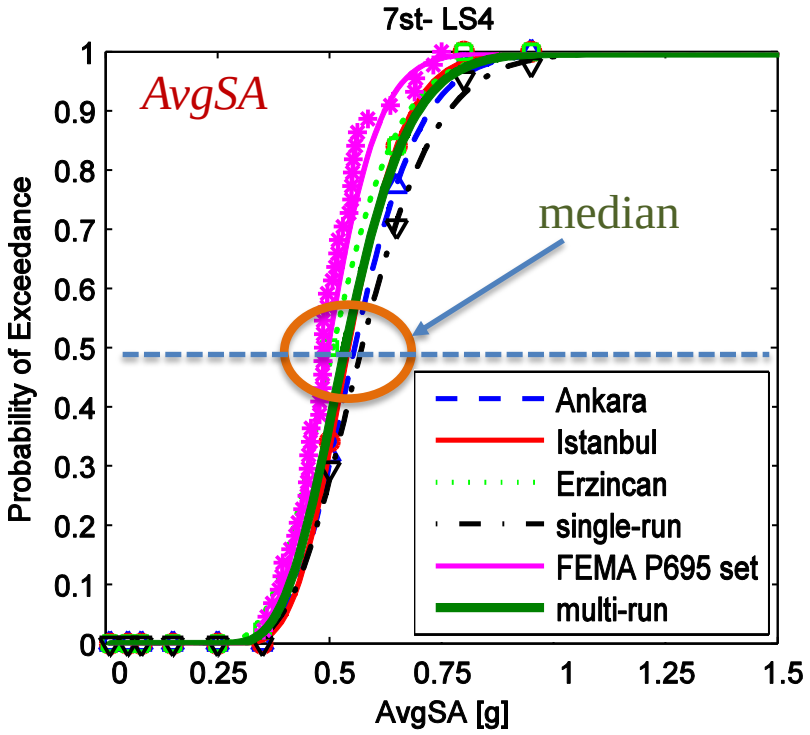


PRESULTS/Fragility curves

General findings: MIDR

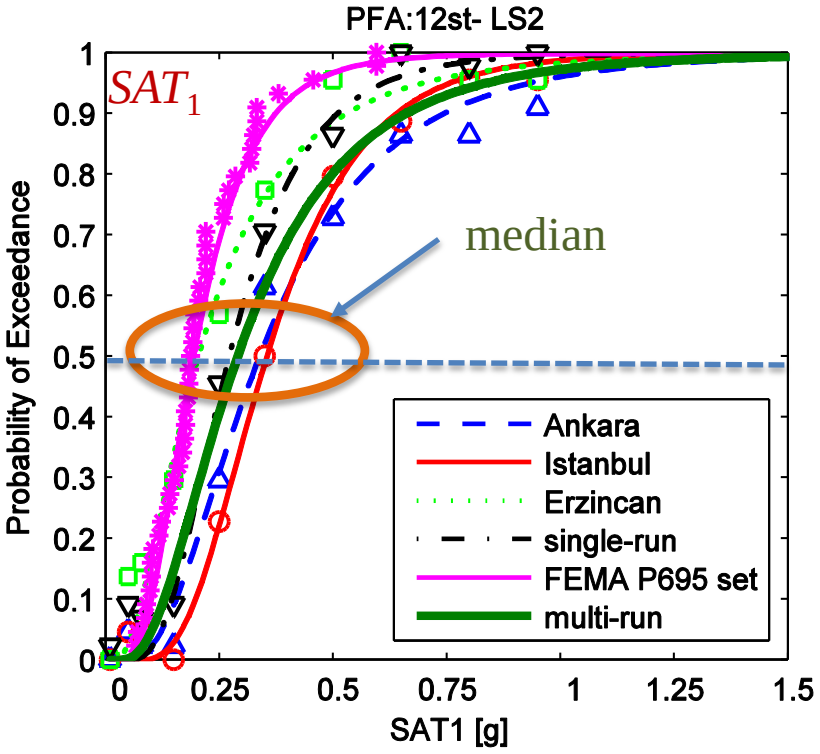
- Building fragilities are site-dependent
- IDA with records regardless of the seismicity of the region → less reliable fragilities
- Fragilities based on *AvgSA* → less scatter than SAT_1
- The two methods proposed here provide very similar results → (Single run ~ multi run)
- To avoid heavy computations: use Single run → one record set, NDA once!

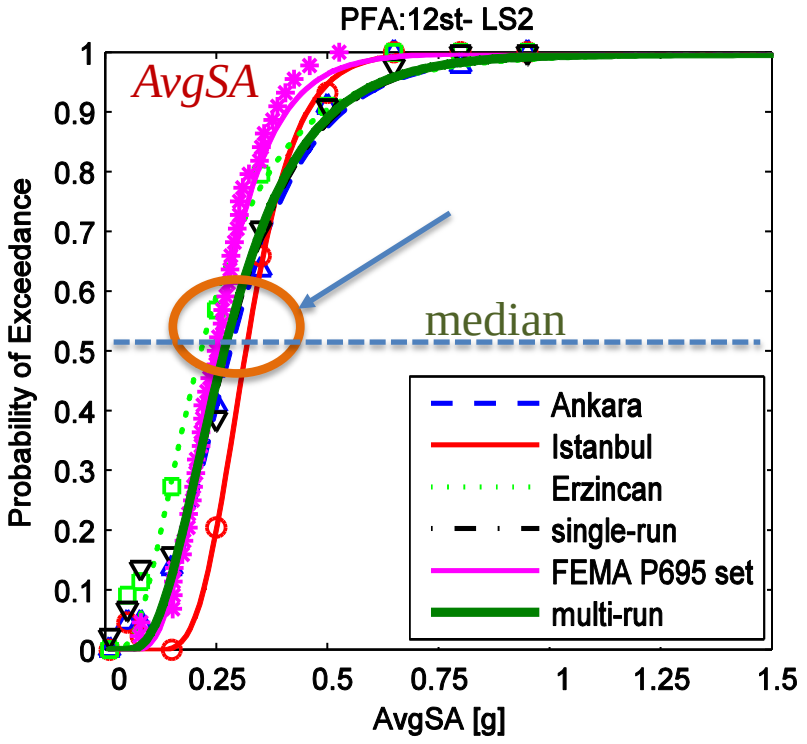




RESULTS/Fragility curves

General findings: MPFA

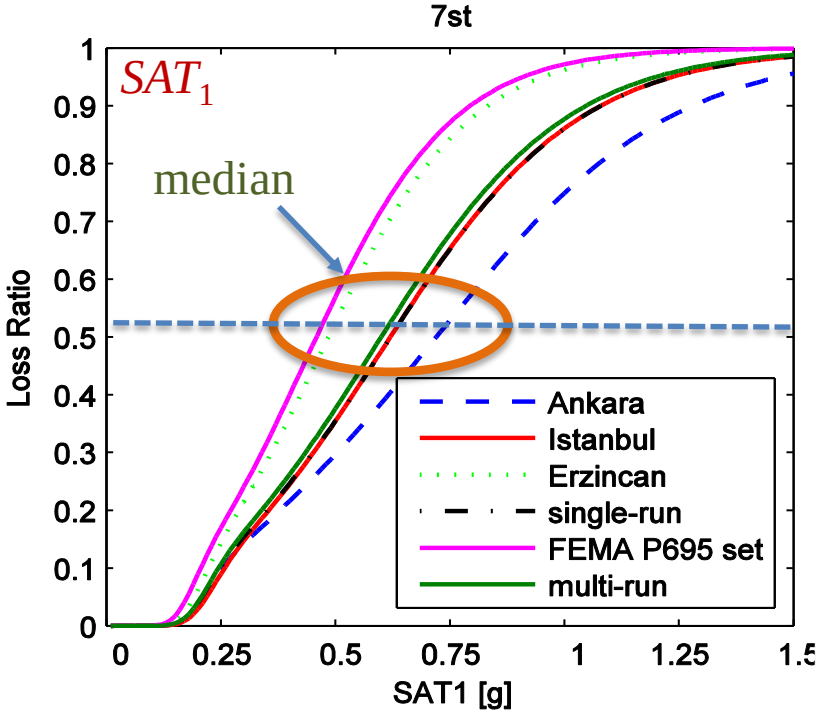


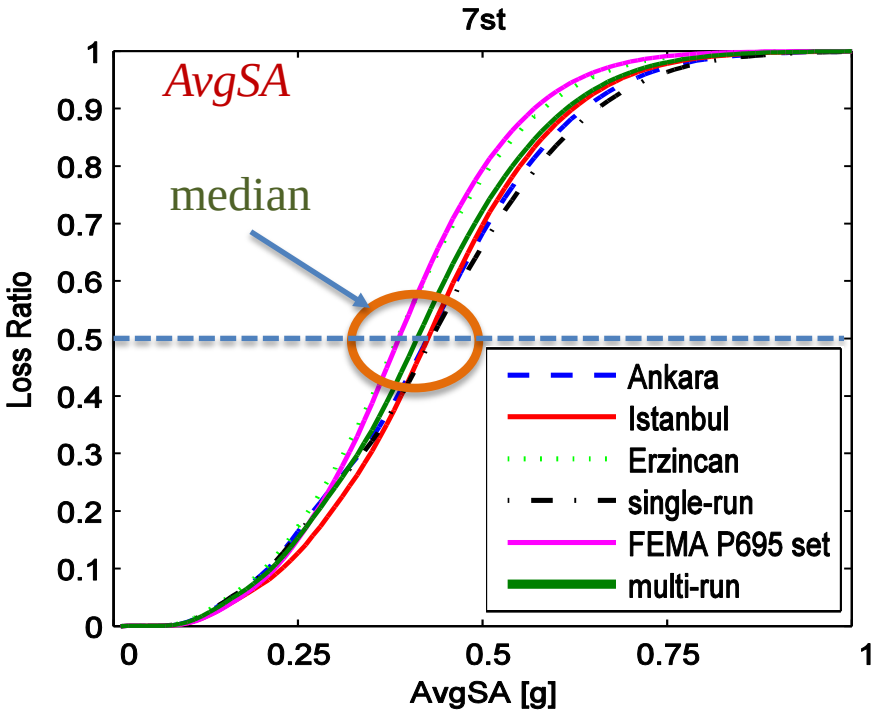


RESULTS/Vulnerability functions

General findings: MPFA

- MIDR-based fragilities
- Drift thresholds of 0.75, 1.2, 2.0 and 4.0%
- loss ratios are defined as 0.10, 0.3, 0.6 and 1.0 corresponding to slight, moderate, extensive and near-collapse limit states





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CONCLUDING REMARKS

- Fragility &vulnerability for a set of buildings → analytical approach
- Fragilities → site-dependent → record selection is needed
- Three approaches proposed
- Most accurate → multiple record selection → multiple fragilities
- Easy and acceptable → single record selection → single fragility
- CS(*AvgSA*) reduces the spread in the fragilities

Thank you for your attention!