Input Ground Motions in TBI Guidelines and Case Studies

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Outline

Chapter 5 of TBI Guidelines

1. Seismic Hazard Analysis
   - Probabilistic
   - Deterministic
2. Soil-Foundation-Structure Interaction
   - Input Motion Specification
5. Ground Motion Selection and Scaling
   - Identification of Controlling Seismic Sources
   - Ground Motion Selection & Modification

Ground Motion Selection and Scaling for Case Studies

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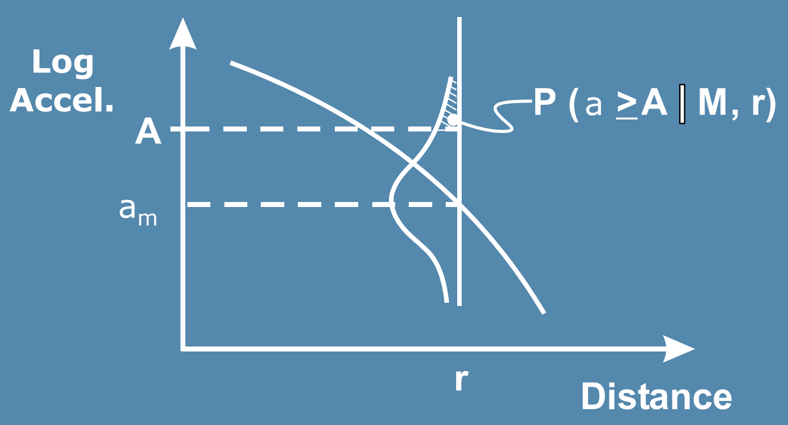
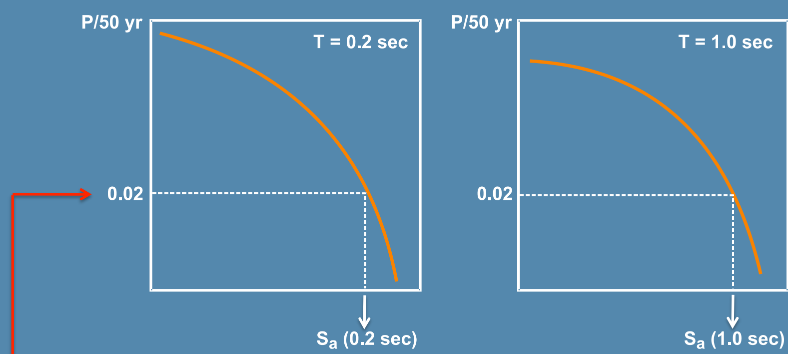
1. Probabilistic Seismic Hazard Analysis (PSHA)

- Seismic source models:
  - Fault geometry; rate of activity; min /max magnitude;…
- Ground motion prediction equations (GMPEs), also known as "Attenuation relations":
  - Median and standard deviation of spectral ordinates; | for given magnitude, site-to -source distance, site condition, …

Ground motion prediction equations (GMPEs)

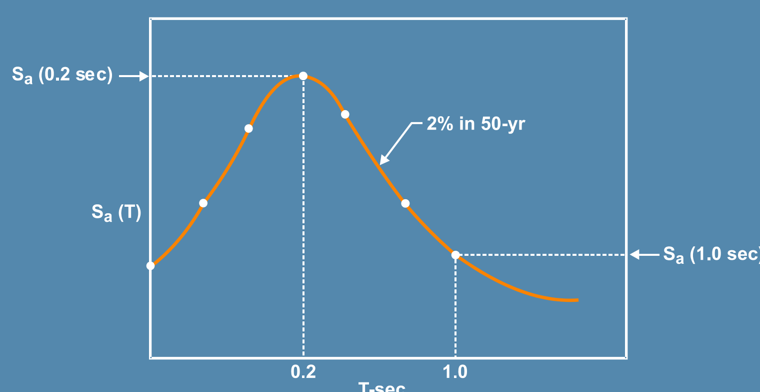


PSHA Output: Ground-Motion Hazard Curves



For example, 2% probability of exceedance in 50 years

Uniform Hazard Spectrum (UHS)



Guidelines Recommendations for PSHA

- For experienced PSHA developers/users only
- Use QA’d software
- Account for alternate seismic source parameters and GMPEs (epistemic uncertainty)

GMPEs Recommended for Shallow Crustal Western U.S. Earthquakes

NGA GMPEs (2008)

- Abrahamson & Silva
- Boore & Atkinson
- Campbell & Bozorgnia
- Chiou & Youngs
- Idriss

- See EERI Spectra Journal (Feb. 2008, v. 24, no. 1)

GMPEs Recommended for Subduction Earthquakes

- Atkinson & Boore (2003) – Site Class B, C, D
- Crouse (1991) – Soil
- Youngs et al. (1997) Soil and Rock
- Zhao et al. (2006) Soil Classes I – IV and Hard Rock

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Deterministic "Cap" for MCE Calculation

- Required per ASCE 7 Ch 21
- Provides a deterministic "cap" near major faults
- Use same GMPEs & weights as used in PSHA
- Different sources may be most critical at short and long periods

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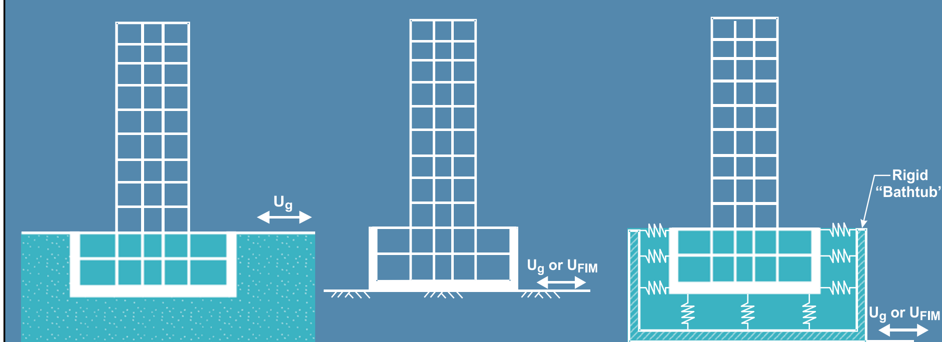
Site-Specific Deterministic Method
ASCE 7, Sect. 21.2.2

- Find Fault → largest median S_a
- ASCE 7-05: Compute 1.5 x median S_a
- ASCE 7-10: Compute $S_a^{84th} > 1.5 S_a^{median}$

2. Soil-Foundation-Structure Interaction (SFSI)



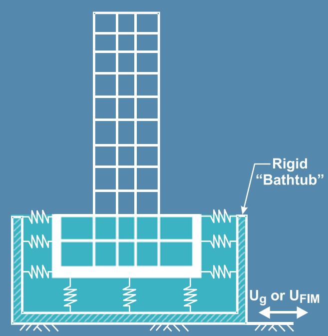
(a) Complete System

(b) Model for service-level earthquake

(c) Model for maximum-considered earthquake

(optional)

SFSI for MCE (optional)



(c) Model for maximum-considered earthquake

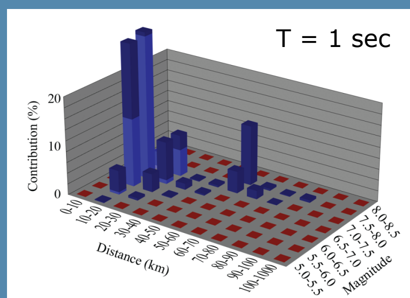
- Linear springs and dashpots model soil -foundation interaction
- Input motion same at all points along foundation

3. Ground Motion Selection and Modification

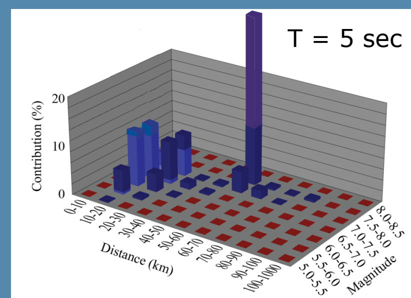
- Identify controlling earthquakes
- Select representative ground motions
- Modify ground motion records to become compatible with target spectrum

Identify Controlling Earthquakes

- Specify natural period band – consult with structural engineer
- Deaggregation Plots



M_1 – R_1



M_2 – R_2

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Number of Recordings - N

- Use at least 7 sets of records
- A set consists of two horizontal components
- Average and maximum structural responses computed using the 7 sets of input motions are considered in the TBI Guidelines
- Standard deviation of structural response from 7 records is not reliable; use COV recommended by TBI Guidelines

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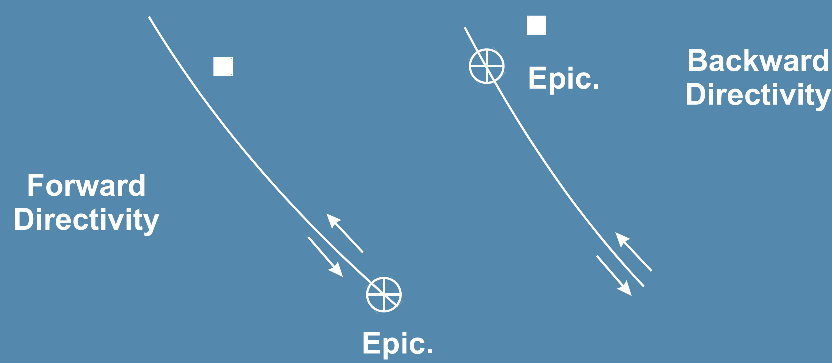
Near Fault Effects



Select a(t) for both cases

Seismological Simulation of Synthetic Ground Motions

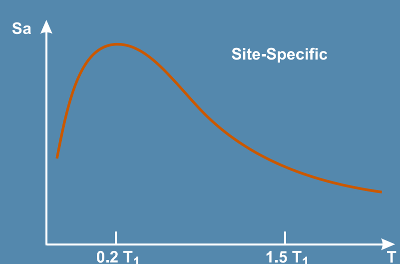
- Can produce realistic-appearing wave forms
- Need for calibration
- Some broadband methods are inadequately validated or have biases

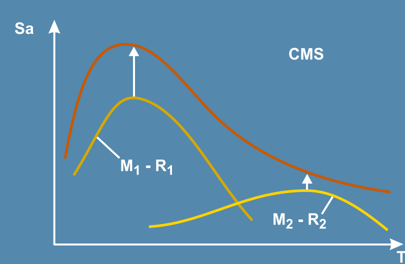
Ground Motion Modification

- Specify target S_a
  - Site-specific S_a
  - Conditional mean S_a (CMS)
- Procedures for record modification
  - amplitude (constant) scaling
  - spectral matching

Target S_a

- UHS encompasses different events
- Not achievable in a given event
- Scenario spectra (CMS) more realistic; need > 1

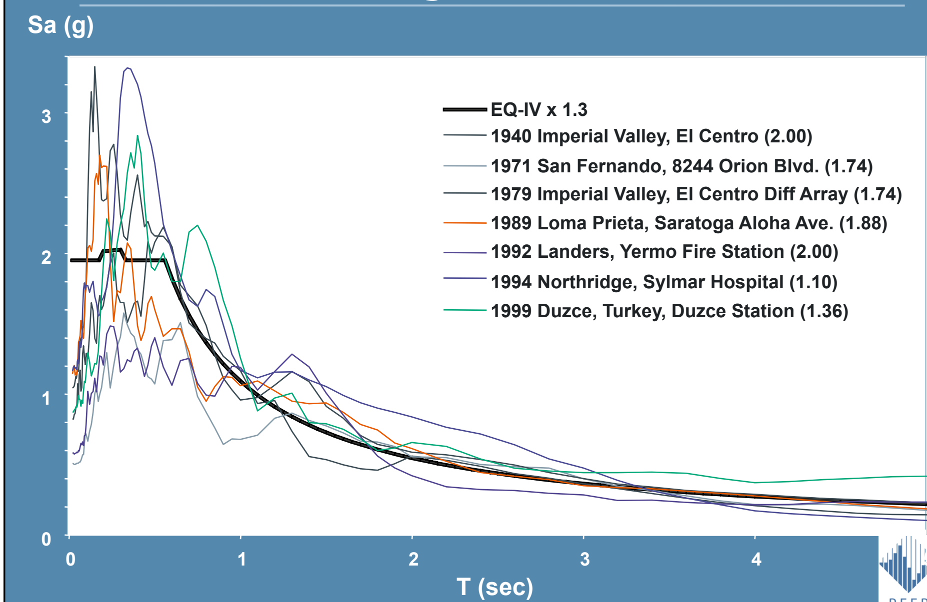




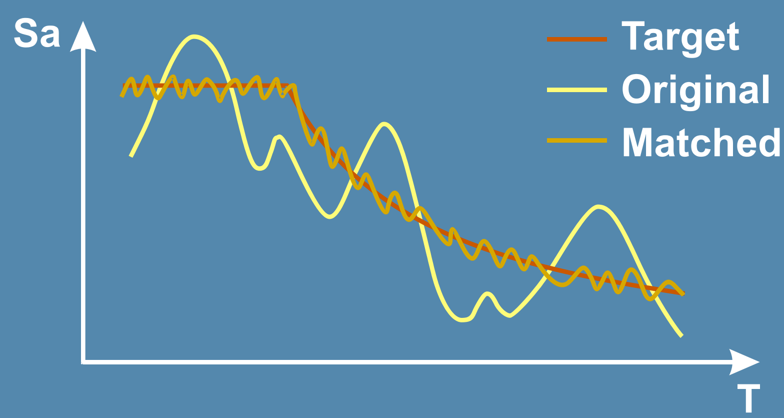
Ground Motion Record Modification

- Amplitude (constant) Scaling
- Spectral Matching

Constant Scaling Method



Spectral Matching



Summary of recommendations on ground motion selection and scaling (**Chapter 5 of TBI Guidelines**)

- N ≥ 7 (N limited by $ and time)
- Use hazard deaggregation → controlling EQs
- CMS – use several → to cover higher models
  - Do not use one CMS for only fundamental period
- Scaling (constant or spectral matching)
- Simulated synthetic ground motions (M ≥ ~ 8)
  - Advantages: large magnitude, long duration and basin effects
  - Disadvantages: verification issues, access to quality simulations
- Peer Review – Important

Ground Motions Developed for Analysis of the Case Studies

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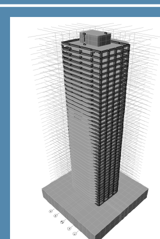
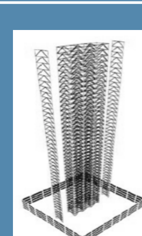
TBI Case Studies

- 42-story reinforced concrete core wall
- 42-story reinforced concrete dual system
- 40-story steel BRB frame





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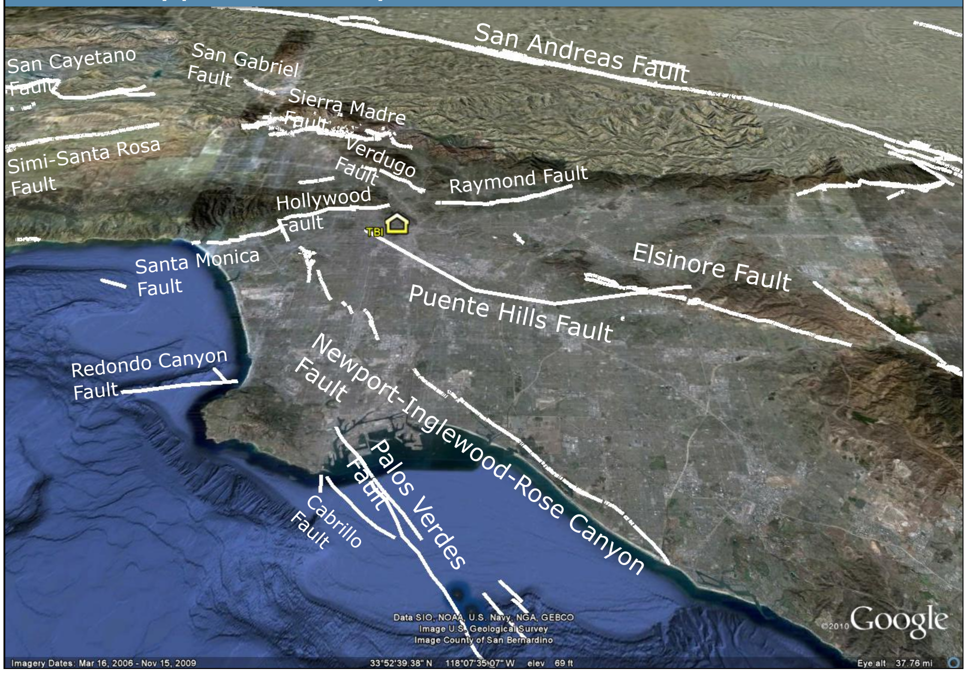
Hypothetically located in downtown LA



Challenges

- Significance of several modes of vibration in response of tall buildings
- Similar ground motions for all structures
- <u>Five hazard levels</u>: 25 to 5000 Return Period
- Relatively large number of motions (<u>15 sets per hazard level</u>) are required to have a reasonable estimate of dispersion in EDP

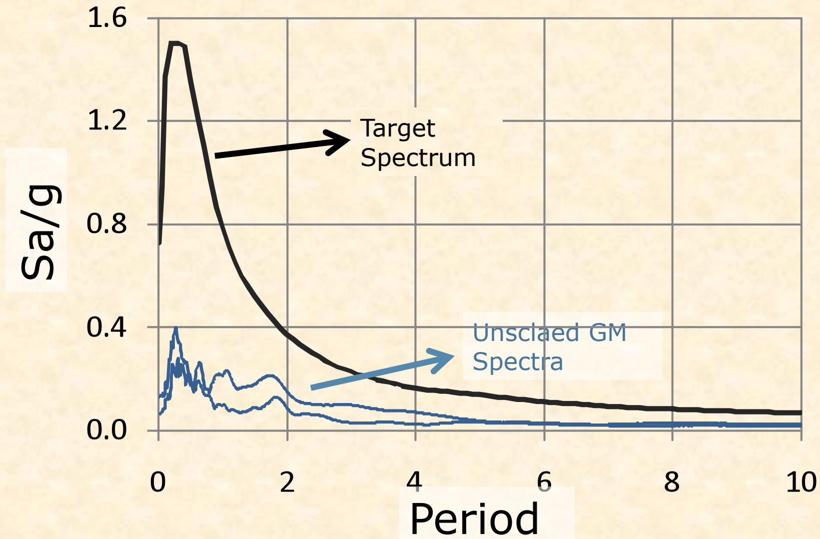
Record Selection and Scaling

- Used a subset of PEER NGA database (no aftershocks)
- Only two recordings from any single event were selected
- No restriction on Magnitude
- R_{min} & R_{max} at 0.0 and 100.0 Km
- Min and Max shear wave velocity = 180 and 1200 m/s
- Low-pass filter cutoff frequency of the selected motions are less than 0.1 Hz (longer than 10 sec)

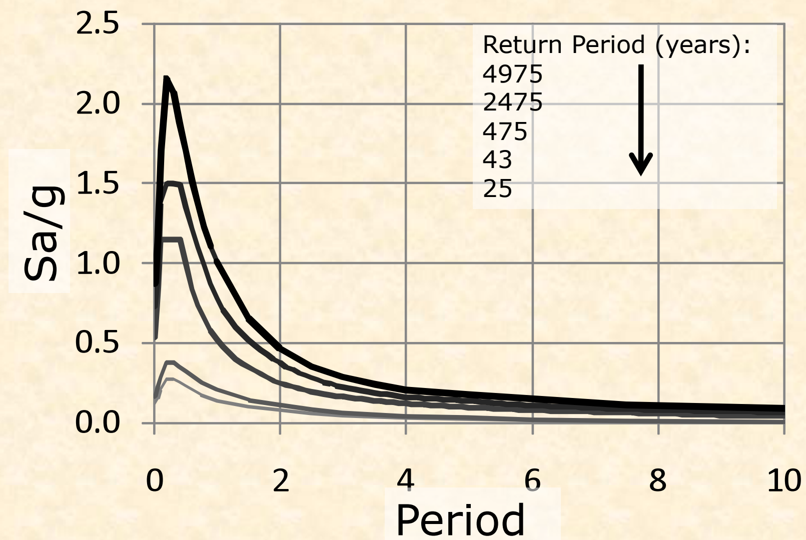
Record Selection and Scaling

- Maximum acceptable scale factor = 5.0
- The scale factor, by which the smallest weighted error between the target spectrum and the geometric mean spectrum of a single recording is acquired, is computed.
- Records are matched between T_{min} & T_{max} at 0.5 & 10.0 sec.
  - Largest T = 6.47 sec. (Bldg. IIIB)   6.47X1.5 = 9.7 sec.
  - Smallest T = 4.28 sec. (Bldg IIB)   4.28X0.2 = 0.9 sec.

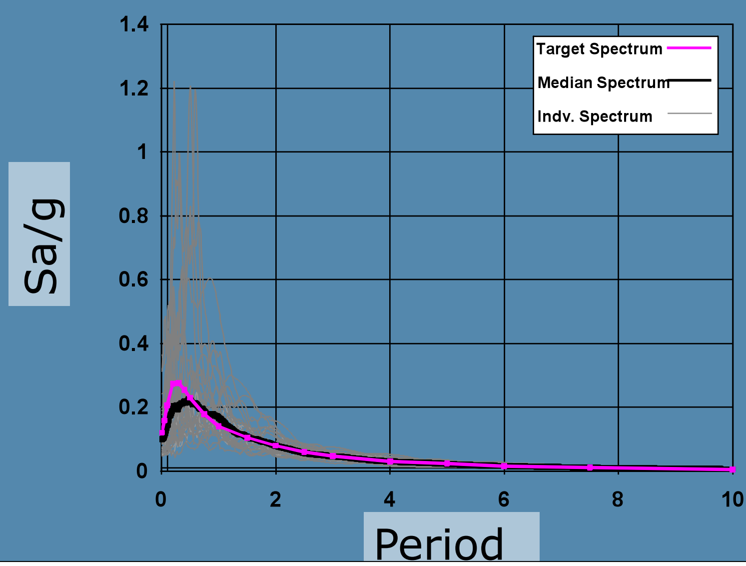
Record Selection and Scaling



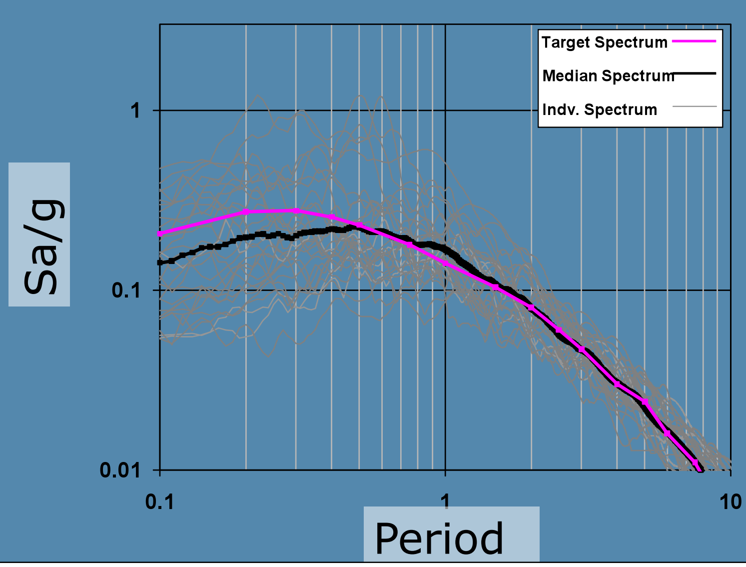
Target Spectra



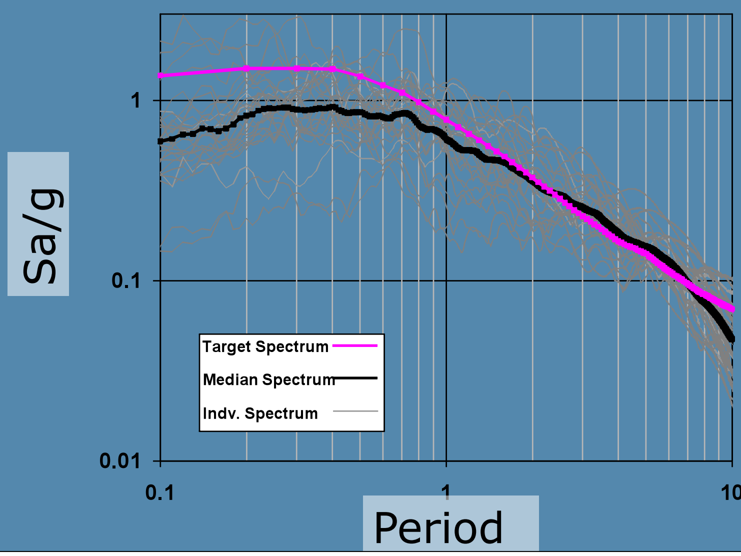
Target Spectrum: SLE-25



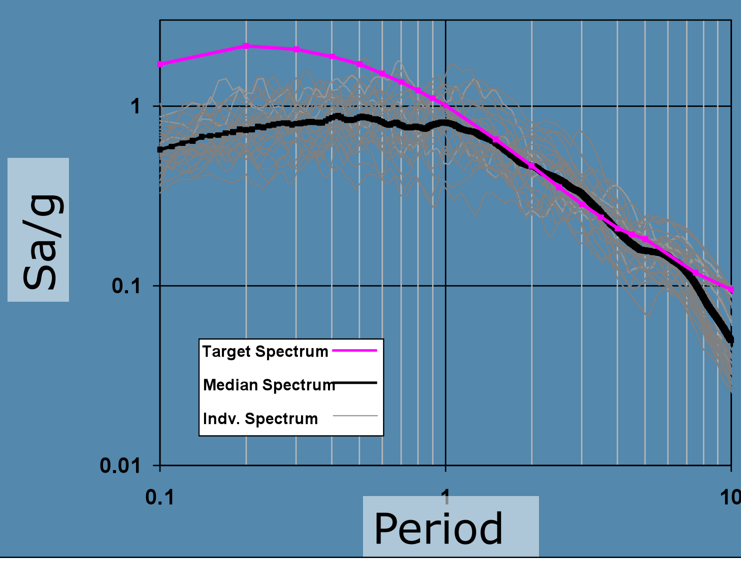
Target Spectrum : SLE-25



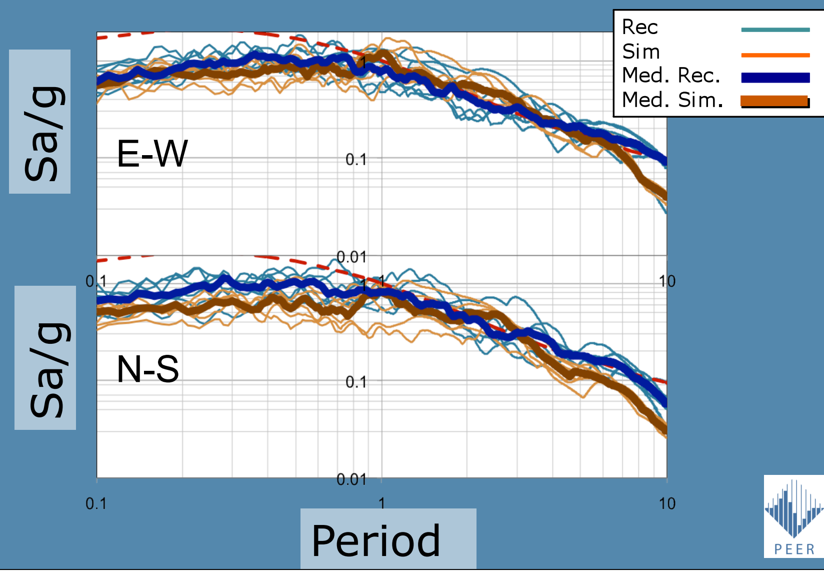
Target Spectrum : MCE



Target Spectrum : OVE



Target Spectrum : OVE



Summary of Selected and Scaled Motions for Case Studies

- 5 sets of 15 ground motion records representing hazard levels from 25 year return period to ≈5000 year return period are selected for the purpose of loss estimation
- Ground motion are matched to the target spectrum for the location of the buildings. (meets code requirements, and similar to procedures used by engineering seismologists)
- Same ground motions are used for all buildings
- For the very low probability hazard level (OVE) a combination of recorded and simulated motions is used


Tall Buildings Initiative