# The PEER Tall Buildings Initiative

# *Guidelines*

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A project funded by
The Charles Pankow Foundation

# TBI Partners

- Applied Technology Council
- California Geological Survey
- California Office of Emergency Services
- California Seismic Safety Commission
- FEMA
- Los Angeles Dept. of Buildings & Safety
- Los Angeles Tall Buildings Council
- National Science Foundation
- Pankow Foundation
- PEER
- San Francisco Building Department
- SCEC
- SEAoC
- USGS

# TBI

- Purpose
  - Develop design criteria and guidance for the seismic design and review of tall buildings
- Tasks
  - Develop consensus on performance objectives
  - Baseline assessment of tall building dynamic response
  - Synthetically generated ground motions
  - Selection and modification of ground motions
  - Modeling and acceptance (ATC-72)
  - Ground motion input to buildings with subgrade levels
  - Quantification of tall building performance
  - Guidelines

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# Performance Objectives

- PEER 2008/101
  - Stakeholders for residential buildings profess to be willing to pay for better performance
  - Concern about losing their investment and homes
- Regardless…
  - Guidelines written to attain code objectives except:
    - control of residual drift limits
    - limited risk of cladding failure at MCE
    - discussion on how to achieve superior performance

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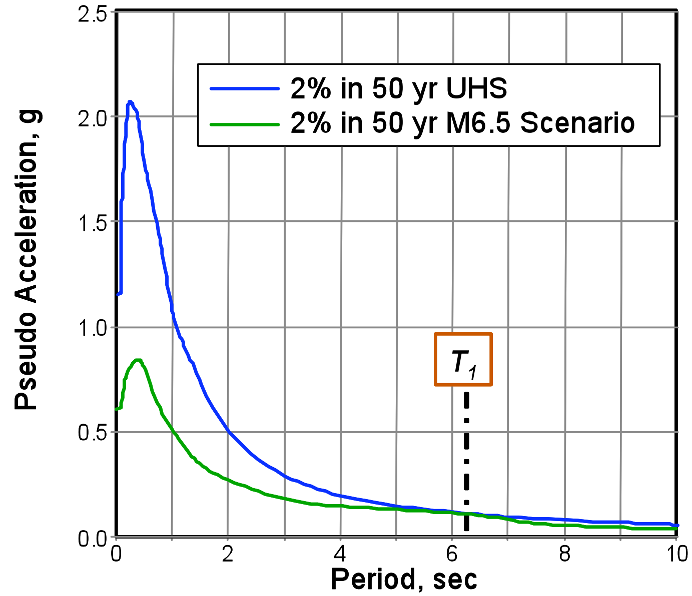
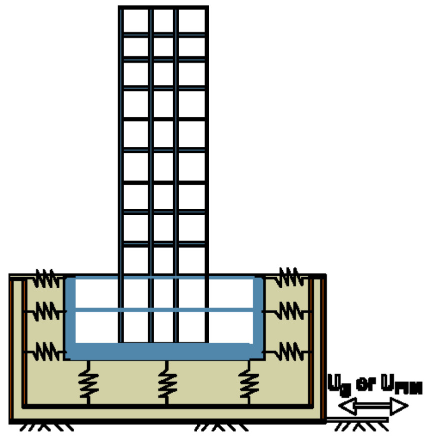
# Ground Motions

- No consensus on use of:
  - Scaled motions
  - Spectrum-matched motions
  - Synthetic motions

- Spectral shape
  - UHS versus scenario spectra (conditional mean spectra)

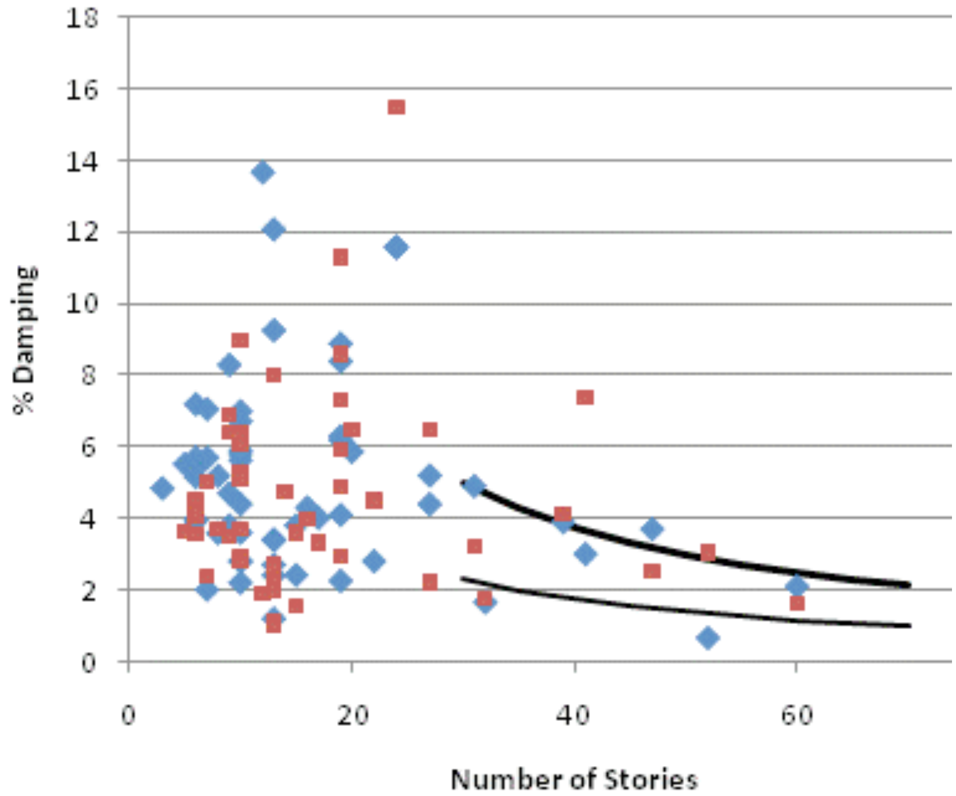
- Motions should be input at base, rather than grade



# Modeling & Acceptance Criteria

- ATC-72
  - General Modeling Considerations
    - …
    - Damping
    - …
  - Specific Modeling Criteria
    - Steel and concrete frame components
    - Concrete core walls

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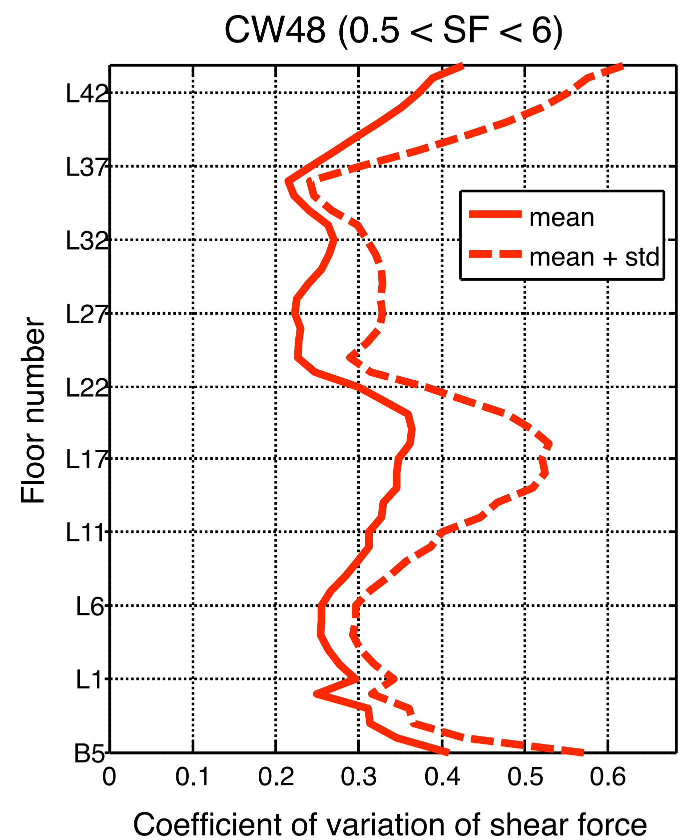
# Performance Quantification

- General response trends




- Trial designs
  - 3 different structural systems
  - One building site
  - 3 design approaches (more later)

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# TBI Guidelines Development Team

- R. Hamburger, J. Moehle – Co-chairs
- Y. Bozorgnia
- C.B. Crouse
- R. Klemencic
- H. Krawinkler
- J. Malley
- F. Naeim
- J. Stewart,

# 1. Introduction

- Purpose
  - Recommended design criteria and procedures:
    - Individual tall buildings
    - Future building code requirements
  - Meet performance goals for Occupancy Category II Buildings

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# 1. Introduction

- Scope – seismic design of tall buildings:
  - Fundamental periods >> 1 second
  - Significant mass participation and response in higher modes
  - Slender aspect ratio
    - Large portion of drift due to flexural behavior as opposed to shear behavior

# 1. Introduction

- Advantages

- Risks

Danger –
Curves ahead!

# 2. Performance Objectives

- Primary Objectives
  - MCE - Low probability of collapse
  - DE – Low probability of life loss
  - Service Level – Low probability of loss of use
- Other Objectives
  - Possible
  - Limited guidance

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# 3. Design Process


1. Confirm approach acceptable
   - Building official
   - Development team
2. Establish performance objectives
3. Seismic input
4. Conceptual design
5. Design Criteria Document
6. Service Level Design
7. MCE Level Design
8. Final Design
9. Peer Review

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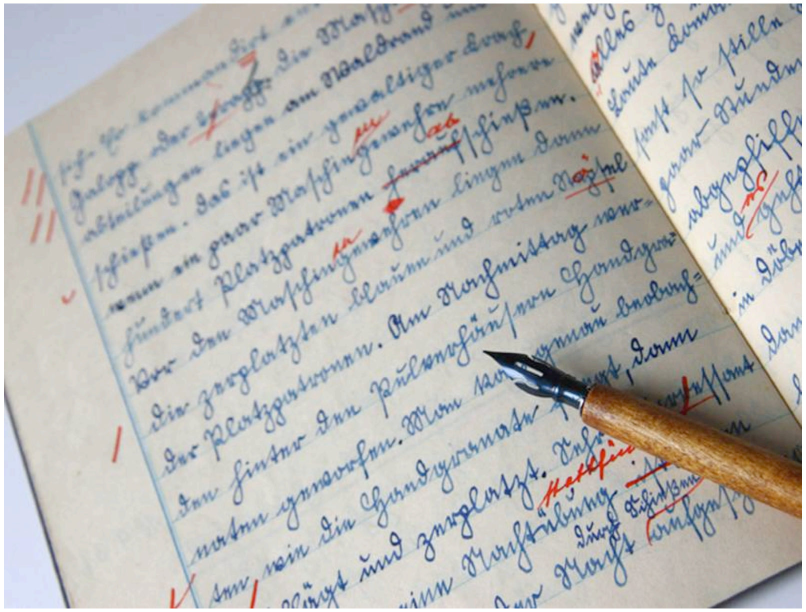
# 4. Design Criteria Documentation



- Building & site description
- Performance Objectives
- Gravity Loading Criteria
- Seismic Hazards
- Wind Design
- Load Combinations
- Materials
- Analysis
  - Procedures
  - Modeling assumptions
  - Software
- Acceptance Criteria
- Test Data
- Appendices

# 5. Seismic Input

- Seismic Hazard Analysis
  - Probabilistic
  - Deterministic
  - Site-response analysis
- Soil-Foundation-Structure Interaction
  - Kinematic
  - Inertial
  - Input motion
- Selection and Scaling of Accelerograms
  - Identification of controlling seismic sources
  - Accelerogram selection guidelines
  - Accelerogram modifications

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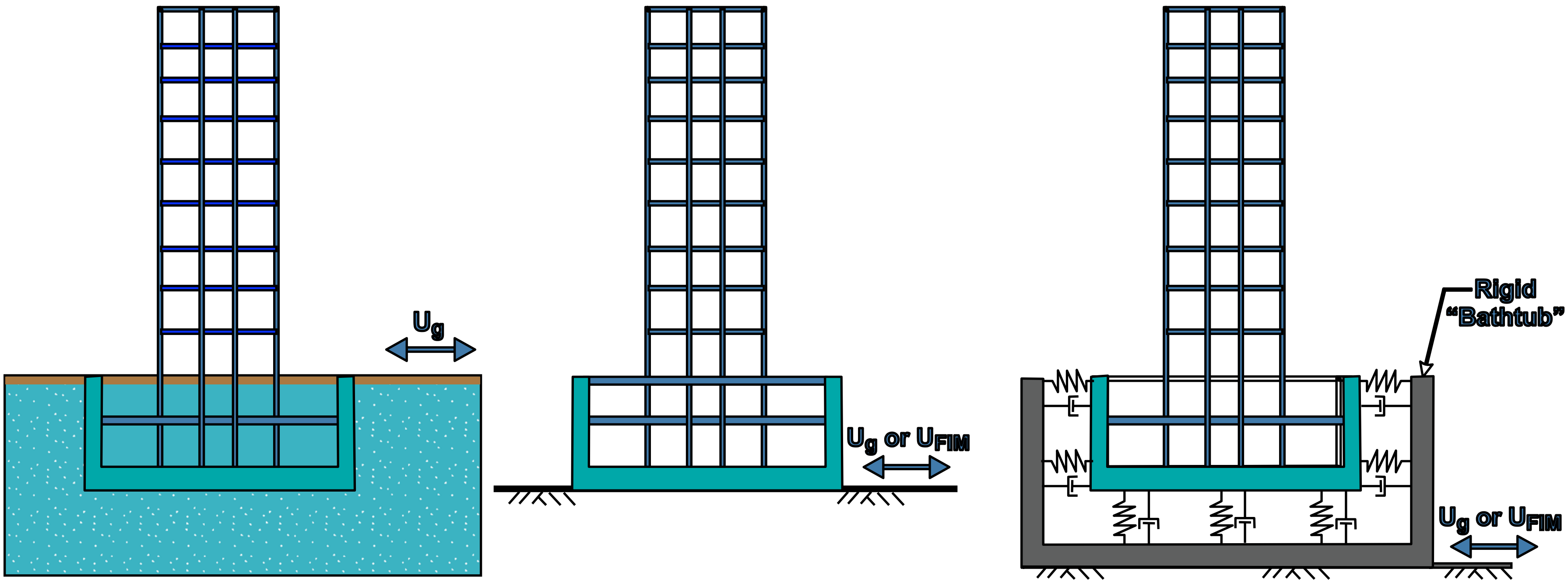
# Soil-Foundation-Structure Interaction (SFSI)




(a) Complete System

(b) Model for service-level earthquake

(c) Model for maximum-considered earthquake

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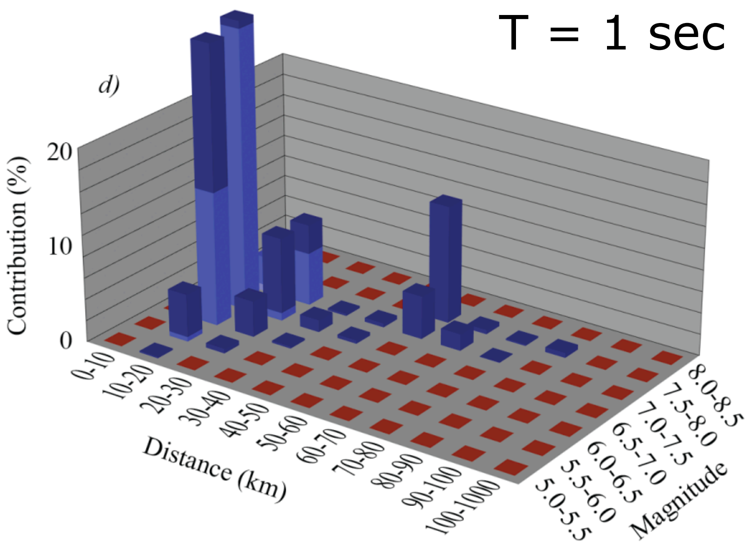
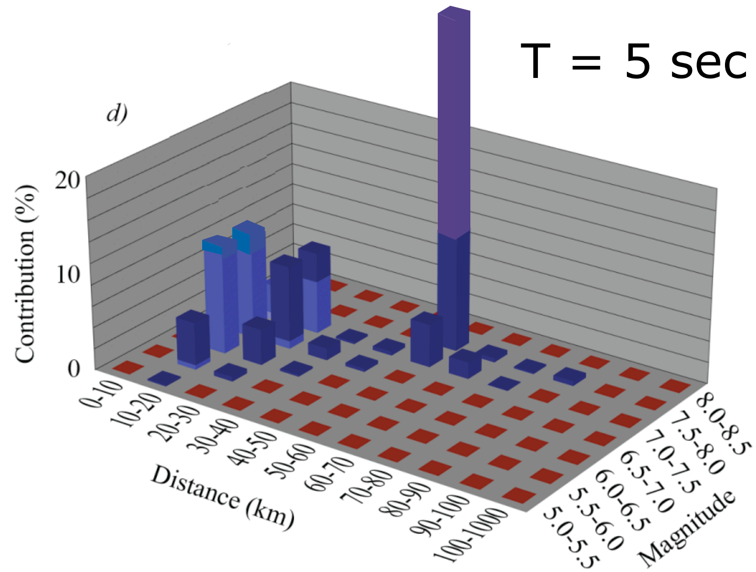
# Identify Controlling Earthquakes

- Specify natural period band
- Deaggregation Plots

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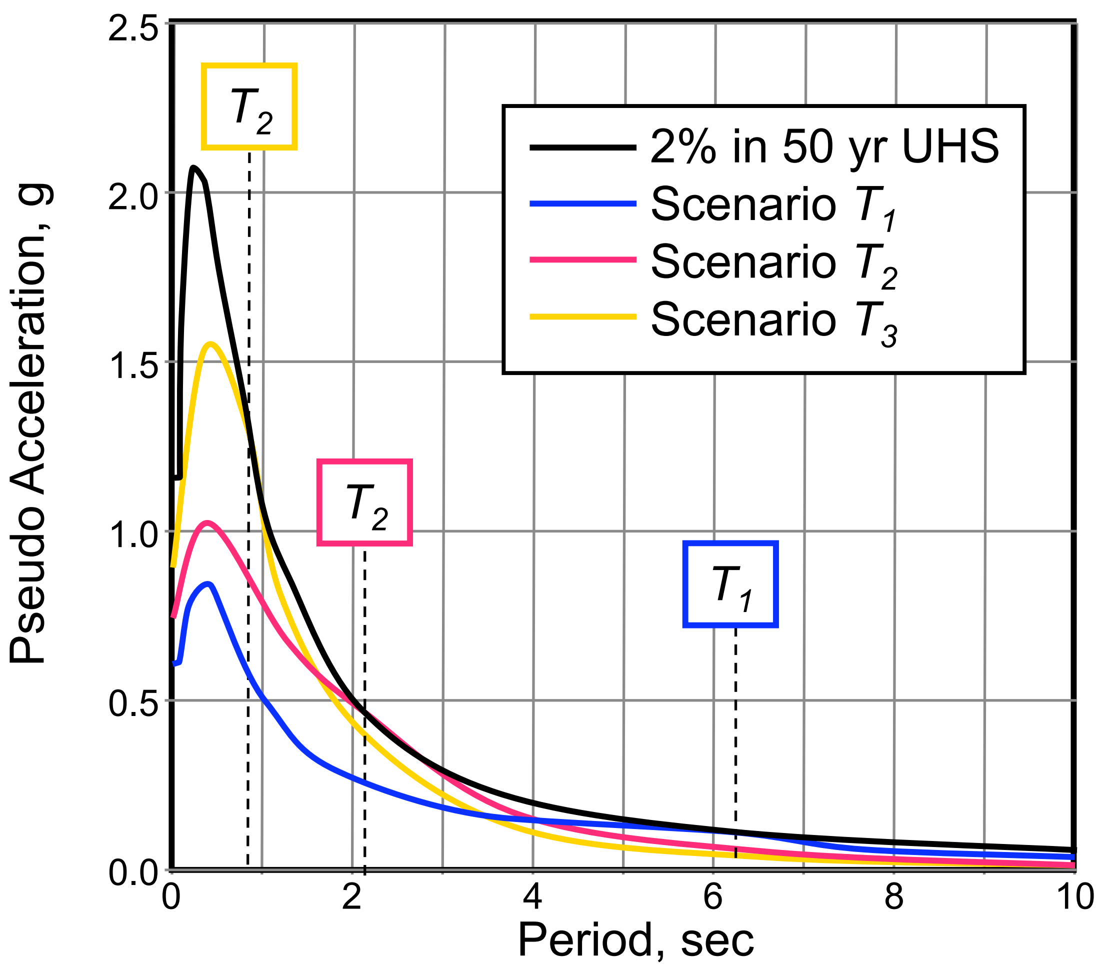
# Scenario spectra

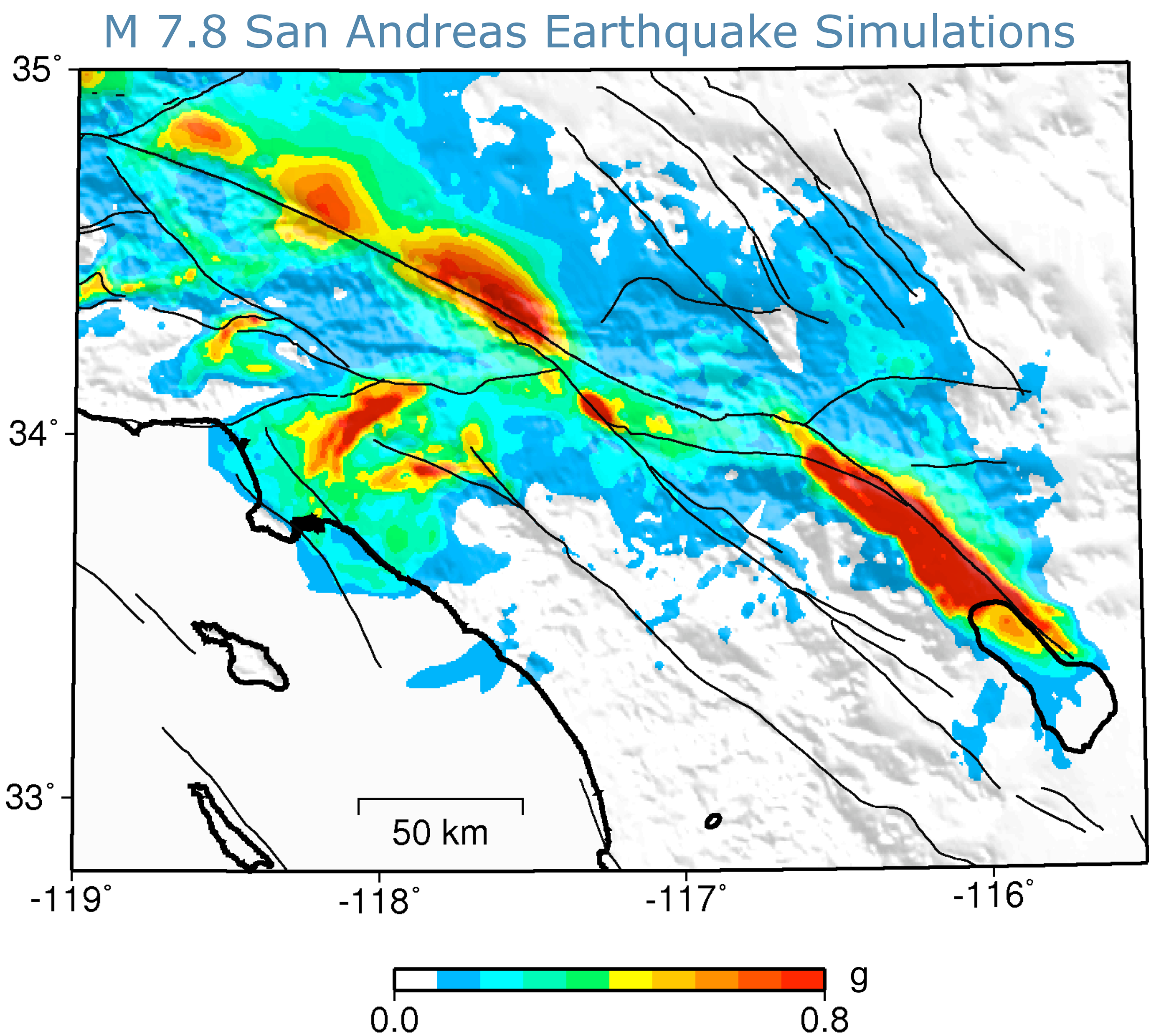



Incidentally…

For each scenario, you need to

1. define the scenario spectrum
2. select and scale at least 7 pairs of earthquake records
3. take the envelope of results as the design value.

# Simulated ground motions

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# 6. Preliminary Design

- Configuration Issues
- Structural Performance Heirachy (capacity-design)
- Wind
- Higher Mode Effects
- Diaphragms
- Nonparticipating elements
- Foundations

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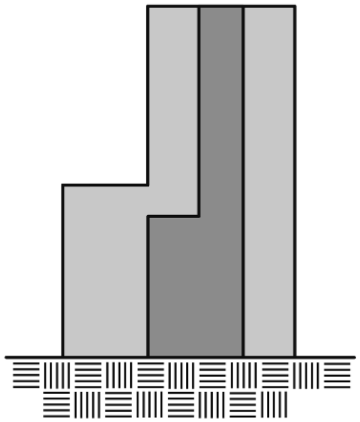
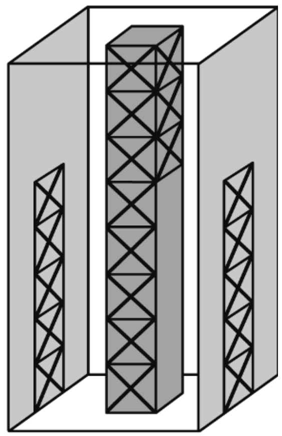
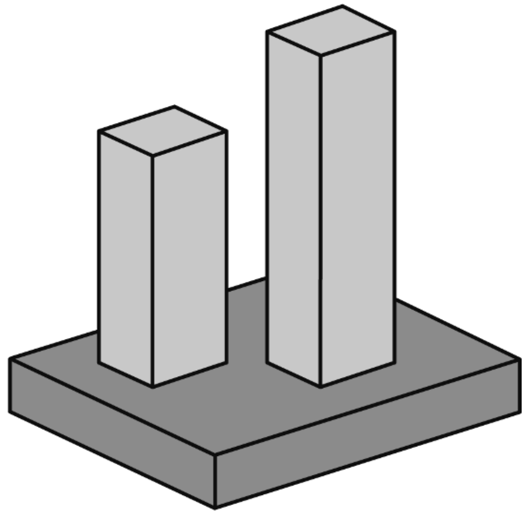
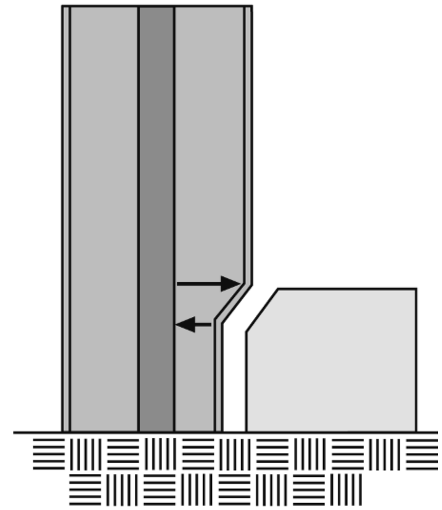
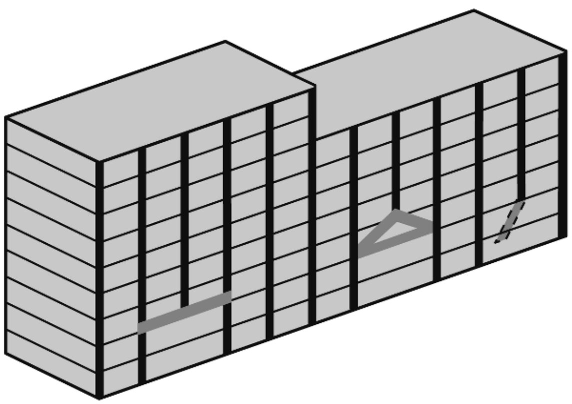
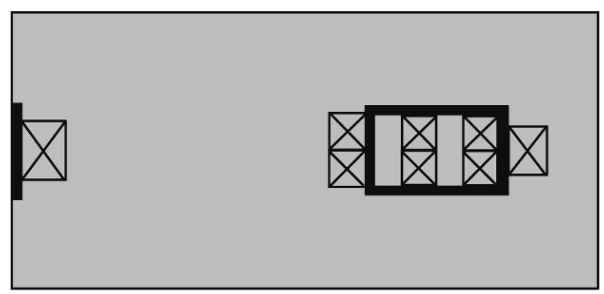
# 6. Preliminary Design

- Configuration issues

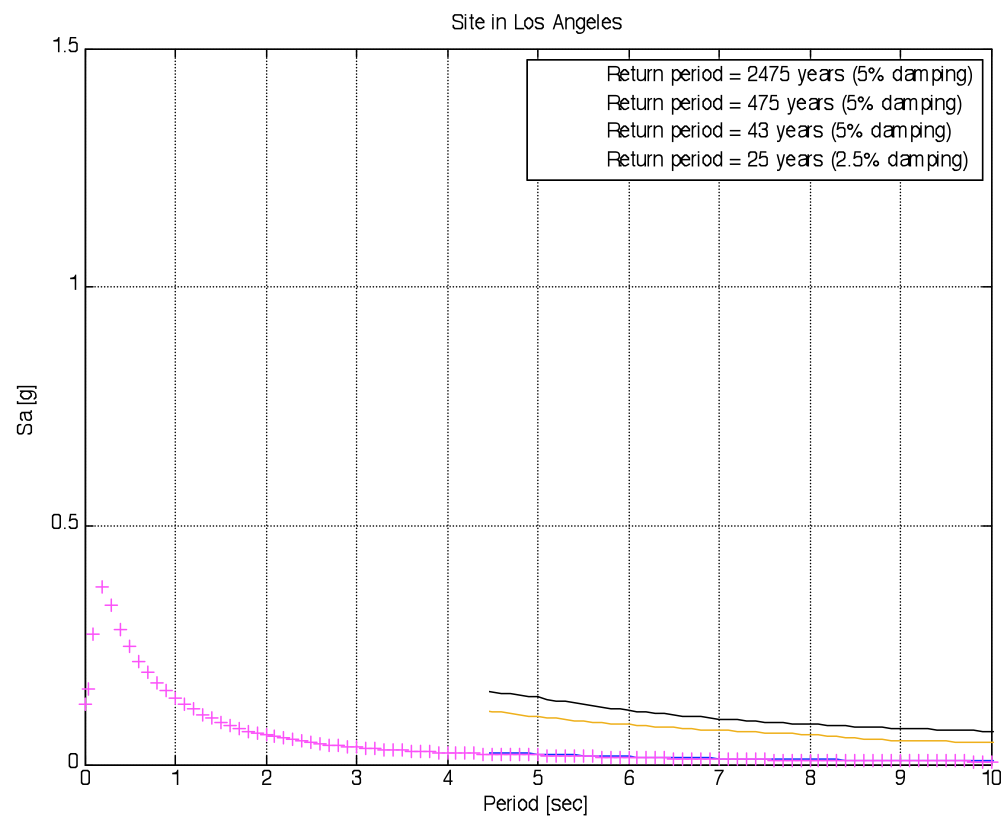







# 7. Service-Level Evaluation

7.1 General
7.2 Service-level Earthquake Shaking
7.3 Analysis Methods
7.4 Performance Objective
7.5 Structural Modeling
7.6 Design Parameters
7.7 Acceptance Criteria

# 7.2 Service-level Earthquake Shaking

- Return period = 25 years
- Damping 2.5% of critical unless you can prove otherwise



# 7.3 Analysis Method

- Nonlinear dynamic analysis is OK, but…
- It is a good idea to get a "second opinion."
  - a 3-D, linear, modal spectral analysis is the recommended option

# 7.6 Design Parameters (continued)

- Response Modification Factors
  - $R = 1$
  - $\rho = 1$
  - $\Omega_0 = 1$
  - $C_d = 1$

# 7.7 Acceptance Criteria

- Modest overstress in limited number of components.
- System drift ratios limited (still under discussion, but likely D.R. $\leq 0.005$)

# 8. MCE-Level Evaluation



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# 8.2 Design and Evaluation Process

1. Capacity design intent as a first cut
2. Nonlinear dynamic analysis to define actual yielding locations and demands
3. Design adjustments as required

# System Performance Criteria

- Mean of max. transient drift in every story ≤ 3.0%
- Max. transient drift in any story ≤ 4.5%
- Mean of max. residual drift in every story ≤ 1.0%
- Max. residual drift in any story ≤ 1.5%
- Gravity framing must be shown adequate
- Avoid excessive loss of strength in any story.  How?

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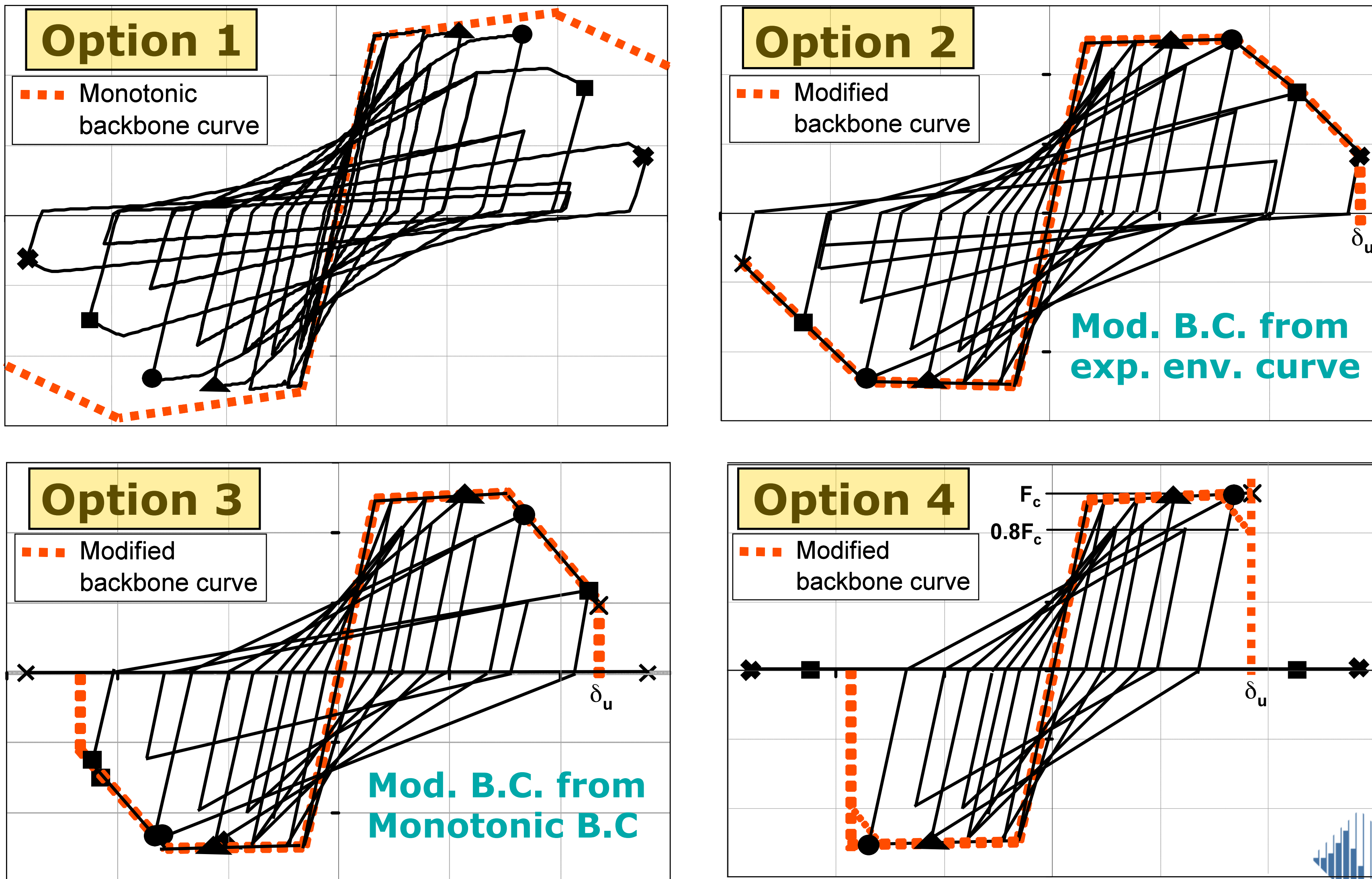
# Modeling Options



# Component Acceptance Criteria

- Force-controlled actions with severe consequences:
- $F_u \leq \phi F_{n,e}$
- $F_u$ = smaller of
  - 1.5 times mean
  - Mean + 1.3$\sigma$ but ≥ 1.2 times mean
- $F_{n,e}$ = nominal strength based on expected material properties

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# 9. Presentation of Results

- Facilitate review
- Suggested items to include
- Level of detail left to individual designer and reviewers

# 10. Project Review


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