Trends in Demands for Concrete Performance-Based Seismic Design Towers

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DESIGNING THINGS
REDESIGNING THINGS
Introduction

- Performance-based Seismic Design
  - 20-year history
  - Popularity
  - Major benefits

- Drawback: uncertainty
Motivation

- Design for DE/SLE alone is inadequate
  - What else can we do early in project?
- Improve estimation of MCE response using DE/SLE demands
  - Best way to reduce uncertainty
  - Eliminate design by “trial and error”
  - Make MCE truly a “verification” stage
- Large project database
Filter Projects:
- US West Coast
- 2014+
- Peer review signoff
Database

- Number of buildings: 14
- Height: 295’ to 605’ (average 450’)
- Locations: Seattle, San Francisco, Los Angeles
- Building use: Residential, Office, Hotel
- Site class: C or D
- Ground motions: split between CMS/not CMS, 7 vs. 11, and spectrally matched or amplitude scaled
For each building, calculate MCE/DE and MCE/SLE results (base shear and moment)

**Example: Building 1, Base Shear**

- $MCE_x = 20,400$ kips  $MCE_y = 13,850$ kips
- $SLE_x = 4,450$ kips  $SLE_y = 3,400$ kips

- $MCE_x/SLE_x = 20,400/4,450 = 4.58$
- $MCE_y/SLE_y = 13,850/3,400 = 4.07$

- $MCE/SLE = \frac{1}{2} (4.58 + 4.07) = 4.33$
<table>
<thead>
<tr>
<th>Bldg No.</th>
<th>Approx. Bldg Ht (ft)</th>
<th>Primary Use</th>
<th>Base Shear (k)</th>
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Results – Base Shear

Base Shear Amplification Factor (Average of Two Directions)

- MCE/DE Average = 2.9
- MCE/SLE Average = 3.6
Results – Base Moment

- Base Moment Amplification (MCE/SLE)
- Base Moment Amplification (MCE/DE)

MCE/DE Average = 2.1
MCE/DE Average = 3.9
Case Study

- Does the amplification factor at the building’s base apply for the full height of the building?
- Variation due to:
  - Localized yielding
  - Relative stiffness
  - Higher mode effects
  - Spectral shape
  - Boundary conditions
  - Damping
Case Study

Sample building:
- 40-story residential building
- US west coast
- Central concrete core wall
- 5-level basement
North Wall

Shear Stress Ratio, Expressed as Shear Demand / (Ac√fc)

- SLE
- DE
- MCE

East Wall

Shear Stress Ratio, Expressed as Shear Demand / (Ac√fc)
MCE/DE Shear Amplification

![Graph showing the ratio of MCE to DE shear demands across different building heights and walls. The graph includes lines representing the South Wall, West Wall, North Wall, and East Wall, with percentile markers for 10th, 50th, and 90th percentiles.]
Conclusions

- For preliminary proportioning, recommend:
  - 2.5 to 3.5 for MCE/DE wall shears
  - 2.5 to 4.5 for MCE/SLE wall shears
  - 1.8 to 2.5 for MCE/DE overturning moment
  - 2.8 to 5.0 for MCE/SLE overturning moment

- Where possible, use DE for proportioning
  - Less uncertainty

- Keep the variation in mind!
  - Build in “buffer thickness” if possible at certain locations (e.g. base of wall)