Performance-Based Design of Tall Buildings

Jack Moehle
University of California, Berkeley
TBI Sponsors

- Applied Technology Council
- California Geological Survey
- California Emergency Management Agency
- 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 acknowledgment

Sponsors
- TBI Project Advisory Committee (TPAC)
  - N. Abrahamson, Y. Bozorgnia, R. Hamburger, H. Krawinkler, J. Moehle, and F. Naeim
  - P. Somerville (SCEC), M. Lew (LATBSDC), M. Moore, N. Rodriguez (SEAOC), R. Lui (SFDBI)

Task 2 – Performance Objectives
- W. Holmes (Chair), C. Kircher, L. Kornfield, W. Petak, N. Youssef, K. Telleen

Various Technical Studies

TBI Guidelines Development Team

Case Studies
- Designers
  - MKA – A. Fry, B. Morgen, J. Hooper, R. Klemencic
  - REI – T. Ghodsi, J.S. Flores Ruiz, R. Englekirk, C. Massie, Y. Chen, E. Hoda, M. Bravo, K. Lee
  - SGH – A. Dutta, R. Hamburger

- Analysts
  - URS/SCEC – P. Somerville
  - UCB/UBC – T. Yang, J. Moehle, Y. Bozorgnia
  - UCLA – J. Wallace, Z. Tuna
  - UCI – F. Zareian, P. Zhong, P. Jones

- Loss Studies
  - ATC 58 – R. Hamburger, J. Hooper, P. Morris, T. Yang, J. Moehle
  - RMS – N. Shome, M. Rahnama, P. Seneviratna; H. Aslani
1979-1994

Earthquakes ≥ M5.8
Performance-based guidance
Performance objectives

- Base Shear
- Damage Threshold
- Collapse Onset

Frequent (50%/30yr)
MCE (~2%/50yr)
Performance objectives

(a) Ground motions
(b) Structural analysis model
(c) Structural responses
(d) Performance
Trial designs

Three Building Systems

1. 42-story reinforced concrete core wall
2. 42-story reinforced concrete dual system
3. 40-story steel buckling-restrained braced frame
# Building designs

<table>
<thead>
<tr>
<th>Building 1A (Code design)</th>
<th>Building 1B (PBEE design)</th>
<th>Building 1C (PBEE+ design)</th>
</tr>
</thead>
</table>
| ➢ \( V_x = 4581 \text{ kips} \)  
  ➢ \( V_y = 4581 \text{ kips} \) | ➢ \( V_x = 5013 \text{ kips} \)  
  ➢ \( V_y = 6018 \text{ kips} \) | ➢ \( V_x = 6686 \text{ kips} \)  
  ➢ \( V_y = 8151 \text{ kips} \) |
| ➢ B4 – L24: 24”  
  ➢ L25 – Roof: 21” | ➢ B4 – L13: 28” (N-S)  
  32” (E-W)  
  ➢ L14 – L31: 24”  
  ➢ L32 – Roof: 21” | ➢ B4 – L13: 32” (N-S)  
  36” (E-W)  
  ➢ L14 – L31: 24”  
  ➢ L32 – Roof: 21” |
Building designs

Column Sizes
- 18” box col
- 24” box col
- 30” box col
- 36” box col
- 42” box col
- 48” box col
- 54” box col
- 60” box col

BRB Strengths
- 228K BRB
- 304K BRB
- 380K BRB
- 513K BRB
- 589K BRB
- 703K BRB
- 950K BRB
- 1026K BRB

(a)  
(b)  
(c)
## Base Building Costs

<table>
<thead>
<tr>
<th></th>
<th>Core Wall</th>
<th>Dual System</th>
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<tbody>
<tr>
<td>Code</td>
<td>$140 M ($326/sq ft)</td>
<td>$149 M ($350/sq ft)</td>
<td>$341 M ($370/sq ft)</td>
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Davis Langdon
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Davis Langdon
Performance study

Figure 2.1  Location of TBI building in Southern California.
Performance study

Figure 2.4  PSHA disaggregation for TBI buildings with a 2475-year return period at 3.0 sec.
Performance study

**maximum IDR, building Illa**

**Key**

- Individual earthquake response
- Median of response
- 16th and 84th percentile
## Performance study

### Average Annual Loss

(= Annual Insurance Premium?)

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Performance study

- **Average Annual Loss**
  
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- **Total Cost** = Construction cost + Net present value of insurance premiums

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This code …“is dedicated to the development of better building construction and greater safety to the public, through the elimination of needless red tape, favoritism and local politics by uniformity in building laws; to the granting of full justice to all building materials on the fair basis of the true merits of each material; and to the development of a sound economic basis for the future growth of cities through unbiased and equitable dealing with structural design and fire hazards.” …1946 UBC