Performance-Based Design of Tall Buildings

Jack Moehle

University of California, Berkeley

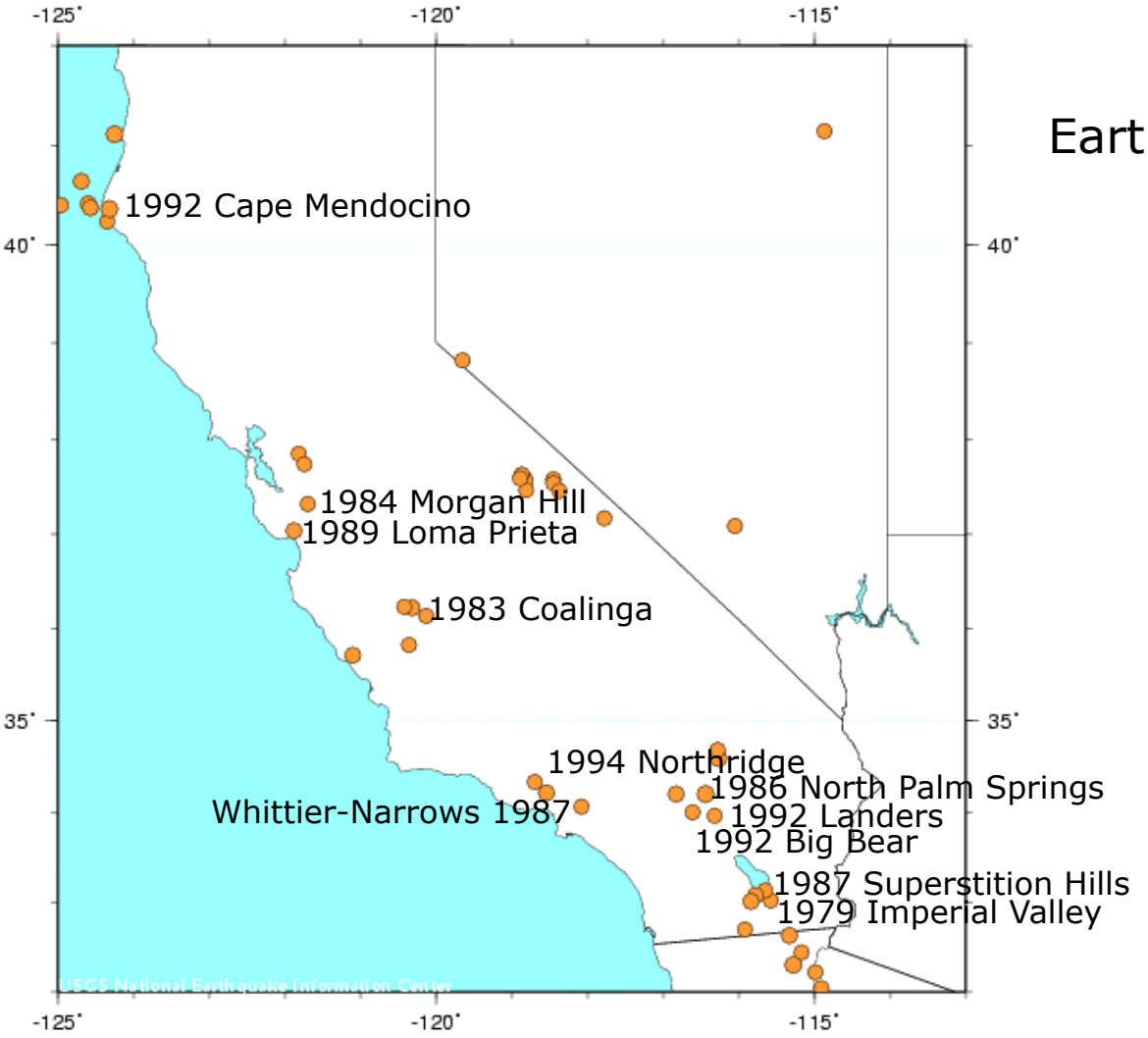
TBI Sponsors

- 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

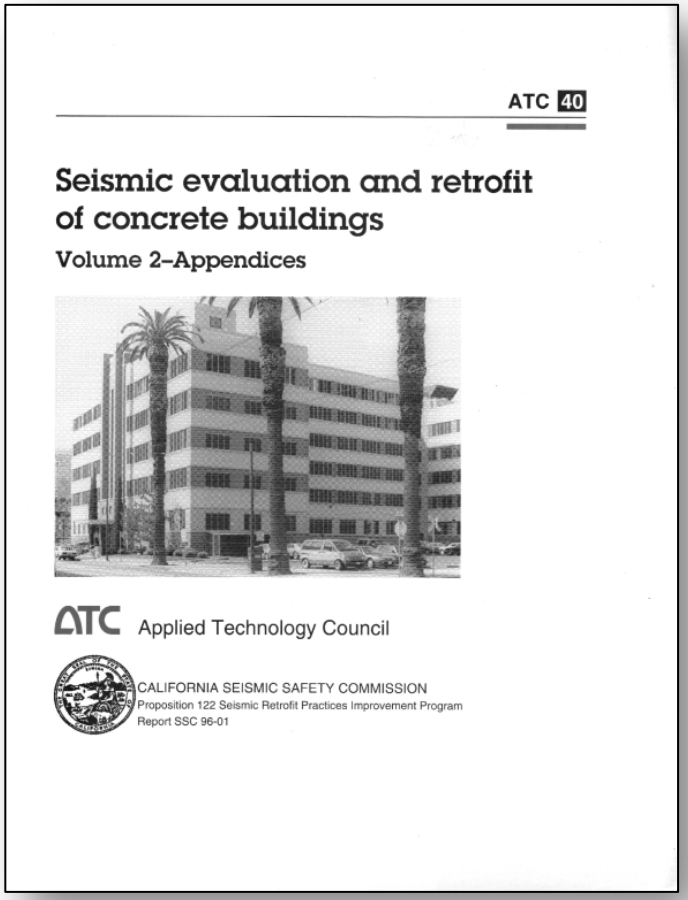
- Sponsors
- TBI Project Advisory Committee (TPAC)
  - N. Abrahamson, Y. Bozorgnia, R. Hamburger, H. Krawinkler, J. Moehle, and F. Naeim
  - P. Somerville (SCEC), M. Lew (LATBSDC), M. Moore, N. Rodriguez (SEAOC), R. Lui (SFDBI)
- Task 2 – Performance Objectives
  - W. Holmes (Chair), C. Kircher, L. Kornfield, W. Petak, N. Youssef, K. Telleen
- Various Technical Studies
  - N. Abrahamson, Y. Bozorgnia, B. Chiou, C.B. Crouse, G. Deierlein, D. Dreger, M. Gemmill, R. Hamburger, J. Heintz, J. Hooper, S. Freeman, C. Kircher, H. Krawinkler, M. Lew, N. Luco, J. Maffei, S. Mahin, J. Malley, N. Mathias, C. McQuoid, A. Mikami, J. Moehle, M. Moore, Y. Moriwaki, F. Naeim, F. Ostadan, M. Pourzanjani, P. Somerville, J. Stewart, E. Taciroglu, J. Taner, T. Visnjic, J. Wallace, T. Yang, Y. Zeng
- TBI Guidelines Development Team
  - R. Hamburger, J. Moehle, Y. Bozorgnia, C.B. Crouse, R. Klemencic, H. Krawinkler, J. Malley, F. Naeim, J. Stewart
- 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



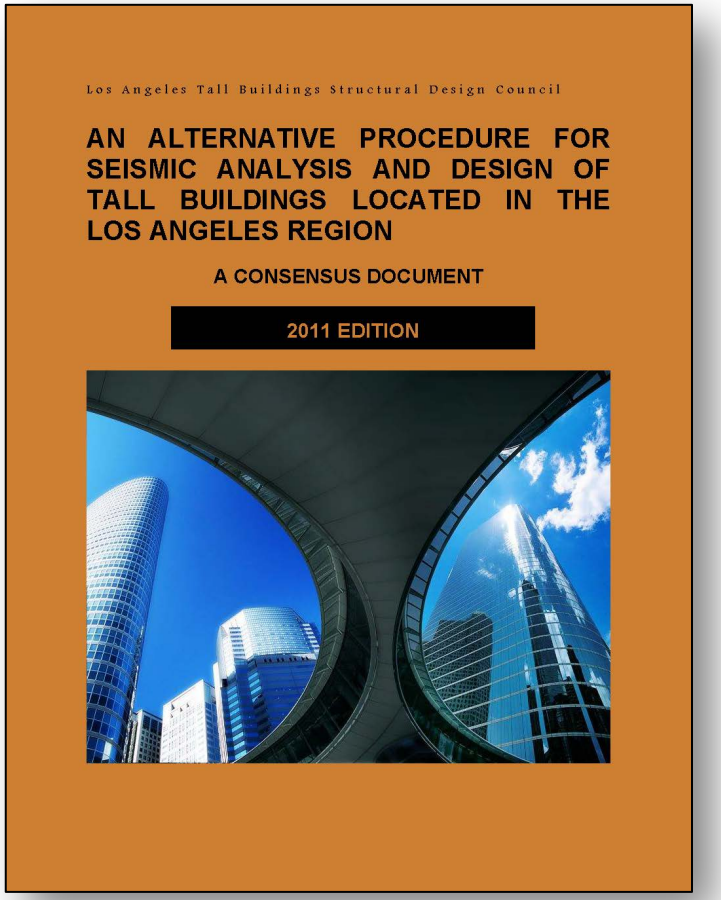
Earthquakes ≥ M5.8

Performance-based guidance



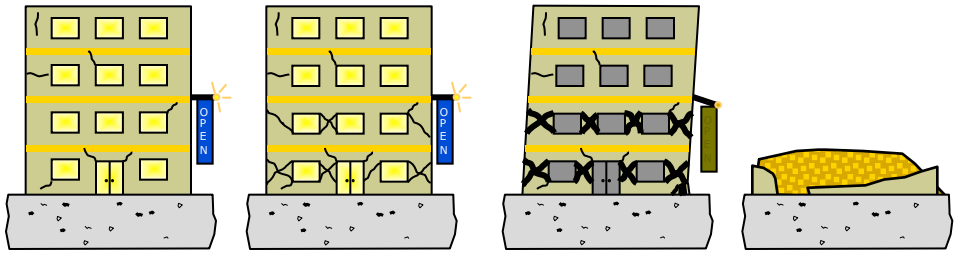
1996

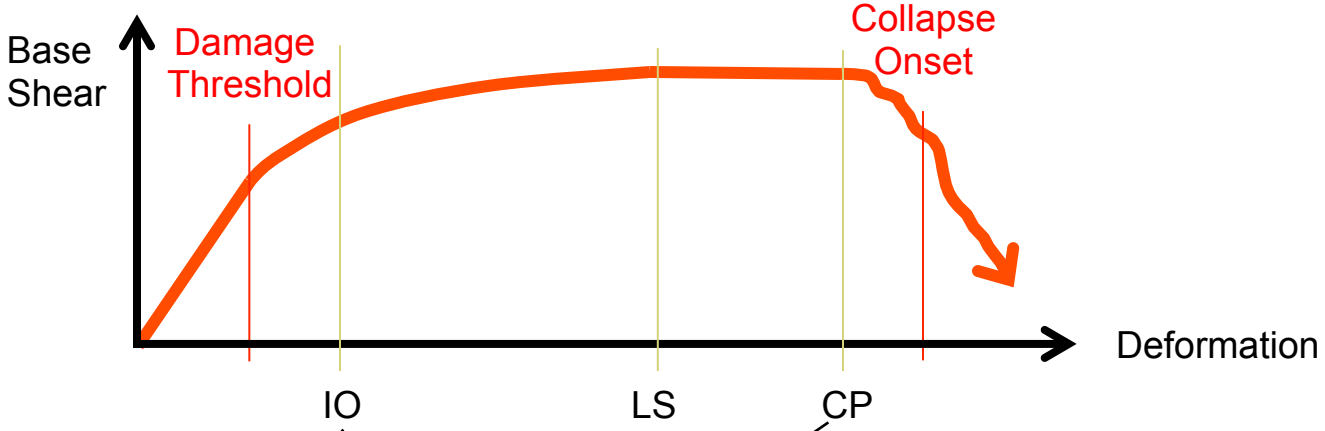
. . .



2006

Performance objectives

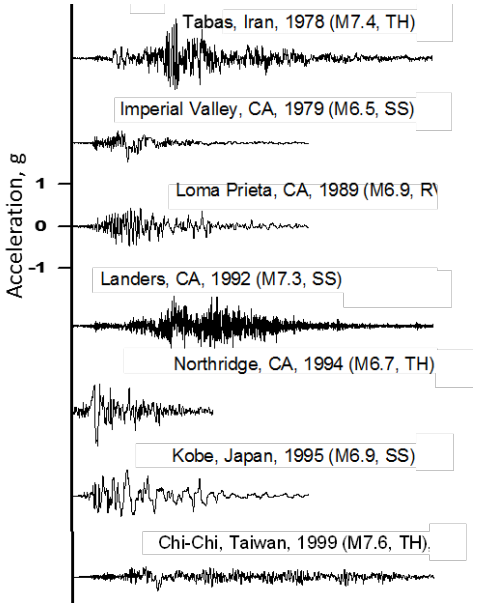




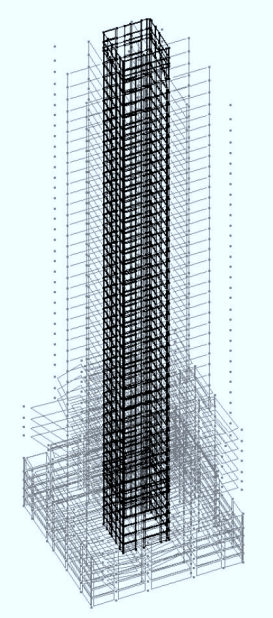
Frequent
(50%/30yr)

MCE
(~2%/50yr)

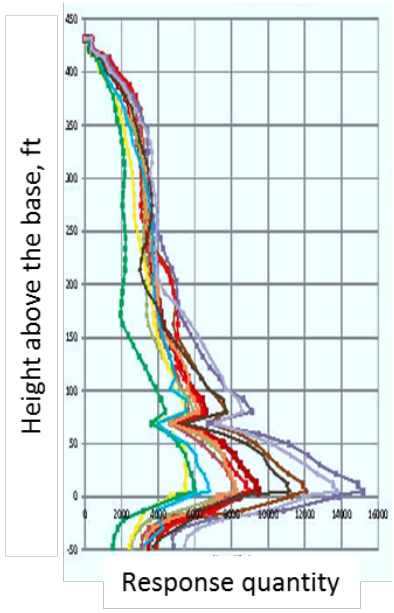
Performance objectives



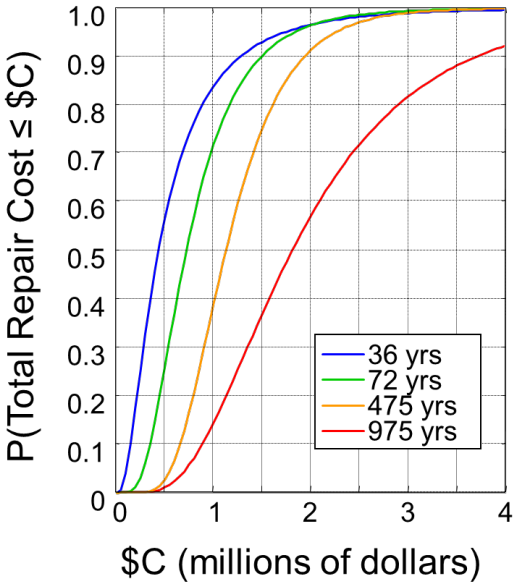
(a) Ground motions



(b) Structural analysis model



(c) Structural responses



(d) Performance

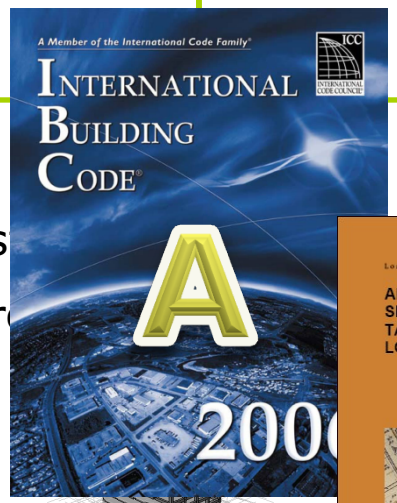
Trial designs

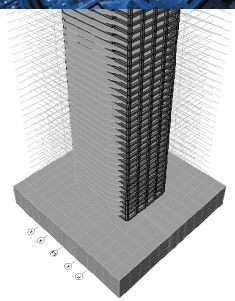
Three Building Systems

42-story reinforced concrete core wall

1

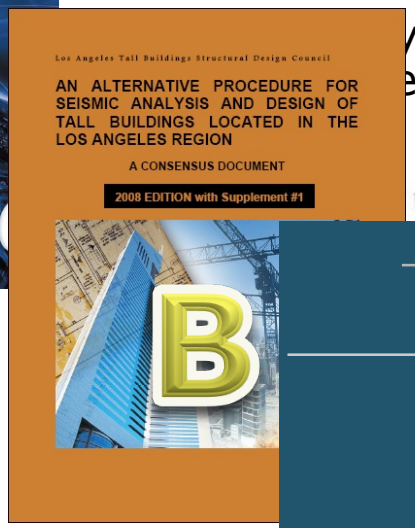
42-s… concr…

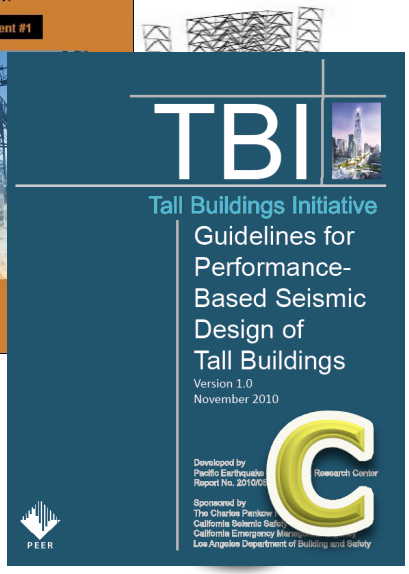




2

…y steel buckling-…ed braced frame

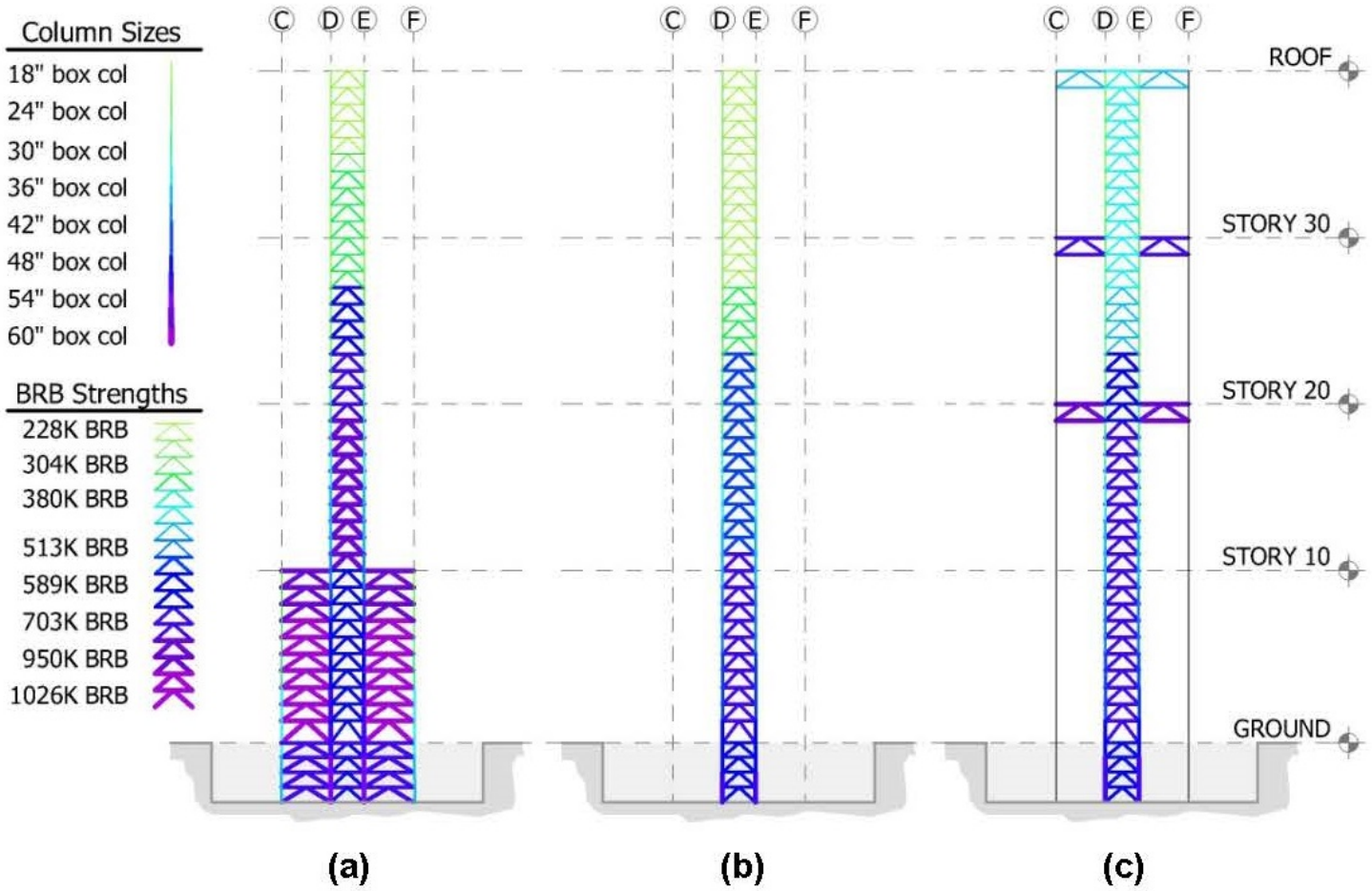




Building designs

Building 1A (Code design)	Building 1B (PBEE design)	Building 1C (PBEE+ design)
➢ V_X = 4581 kips ➢ V_Y = 4581 kips	➢ V_X = 5013 kips ➢ V_Y = 6018 kips	➢ V_X = 6686 kips ➢ V_Y = 8151 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



Base Building Costs

	Core Wall	Dual System	BRBF
Code	$140 M ($326/sq ft)	$149 M ($350/sq ft)	$341 M ($370/sq ft)
TBI Guidelines	$143 M	$174 M	$333 M

Davis Langdon

Base Building Costs

	Core Wall	Dual System	BRBF
Code	$140 M	$149 M	$341 M
TBI Guidelines	$143 M	$174 M	$333 M

Davis Langdon

Performance study

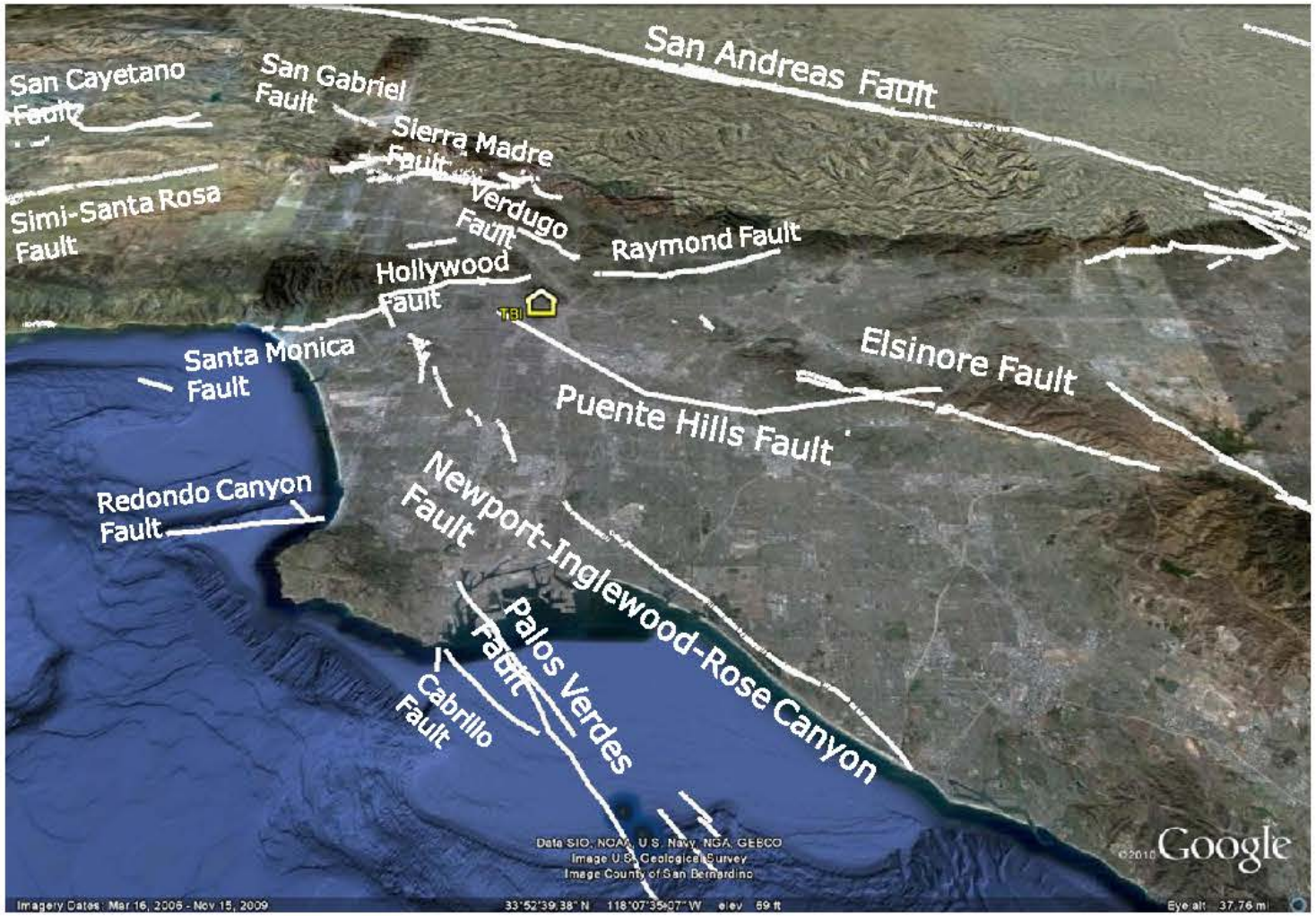


Figure 2.1 Location of TBI building in Southern California.

Performance study

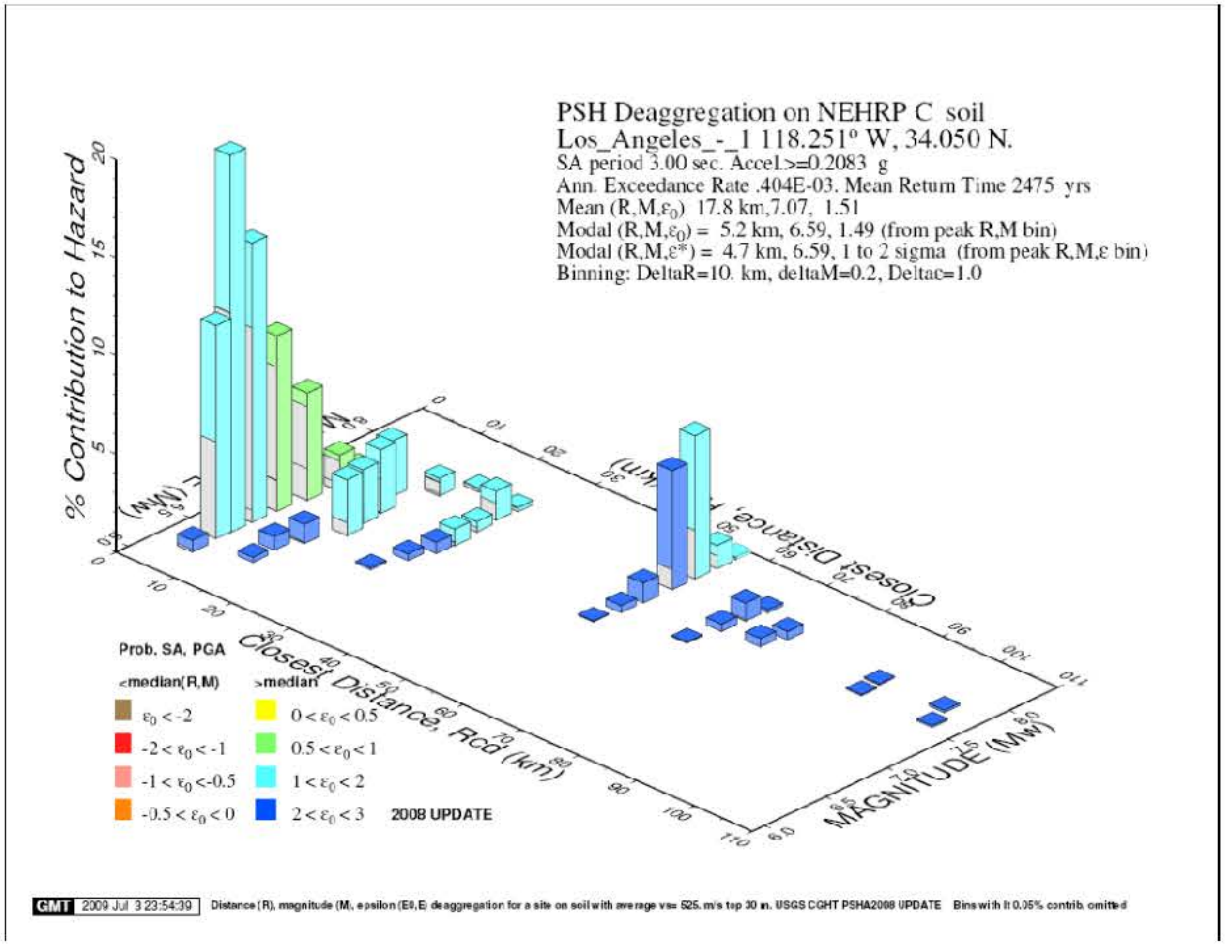
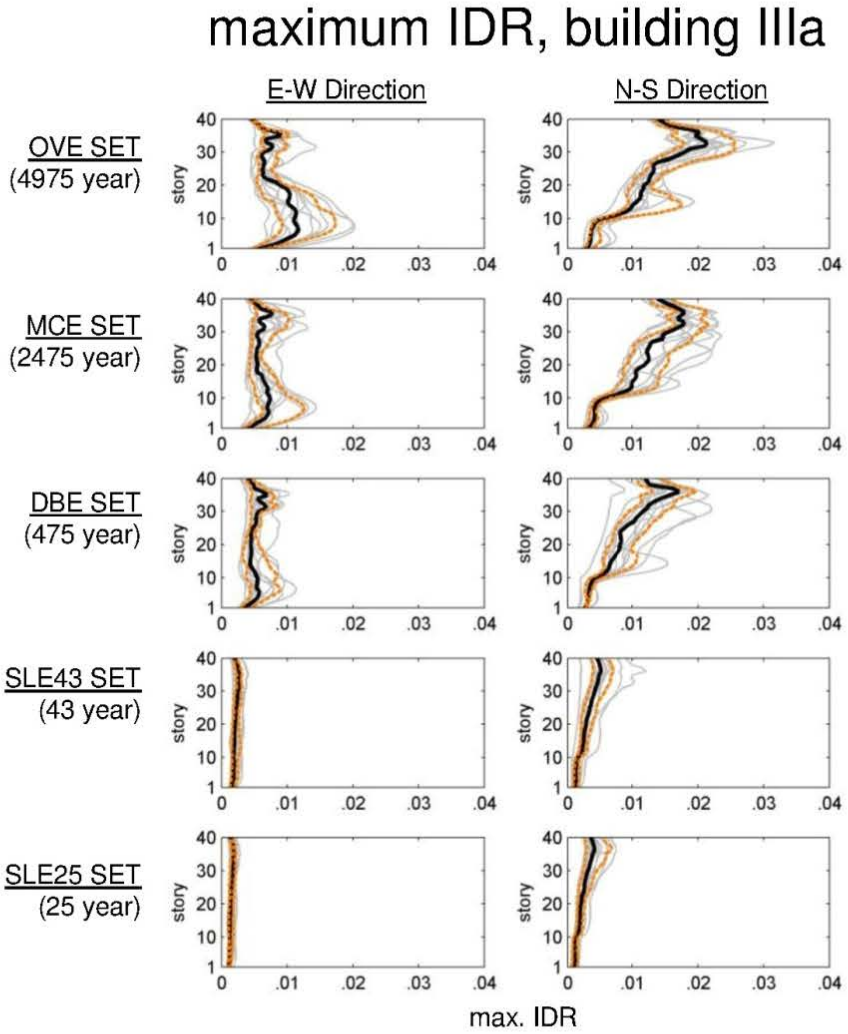
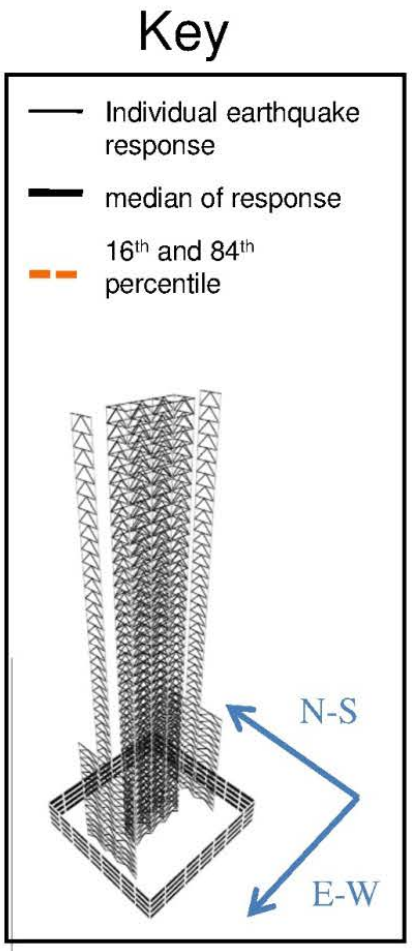


Figure 2.4 **PSHA disaggregation for TBI buildings with a 2475-year return period at 3.0 sec.**

Performance study





Performance study

- Average Annual Loss

(= Annual Insurance Premium?)

	Core Wall	Dual System	BRBF
Code	$326,000	$323,000	$206,000
TBI Guidelines	$282,000	$269,000	$141,000

Performance study

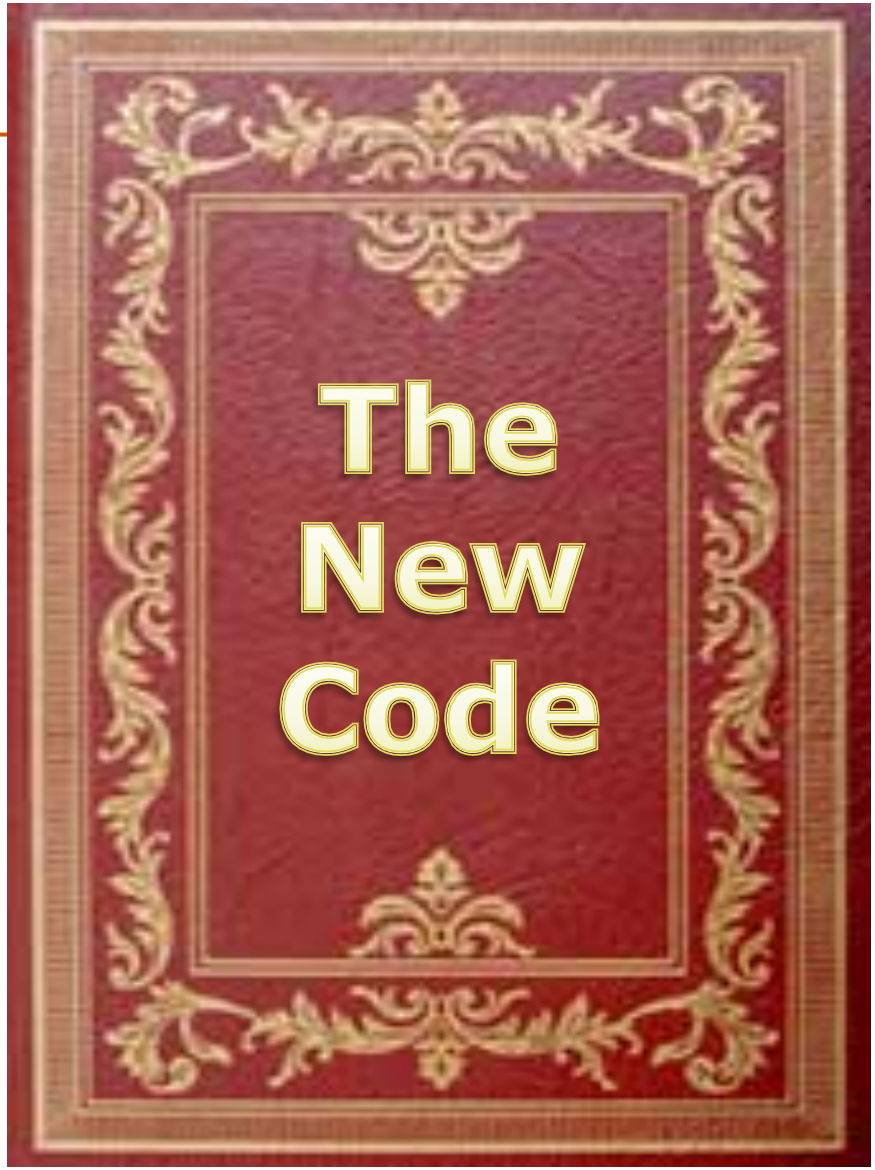
- Average Annual Loss

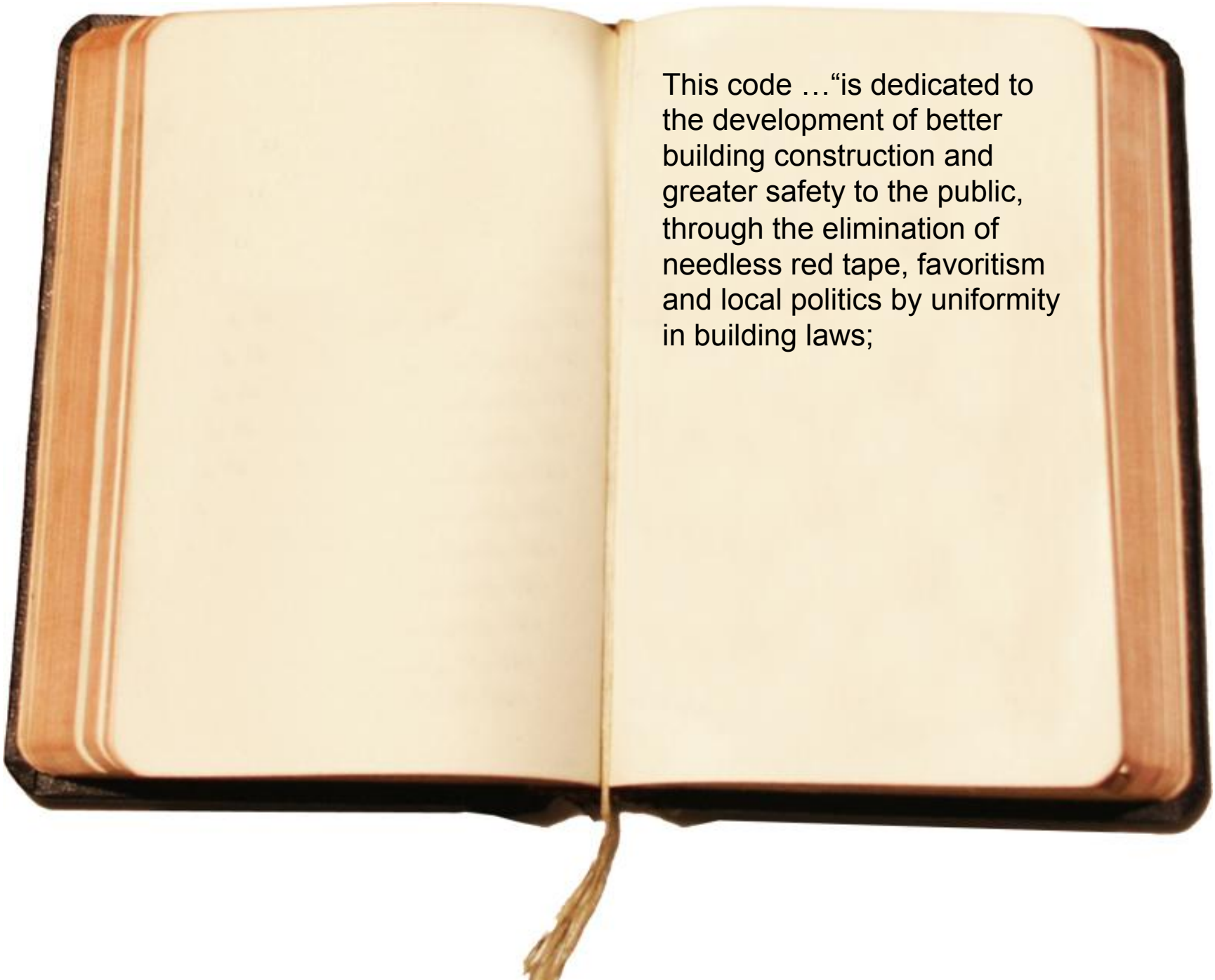
(= Annual Insurance Premium?)

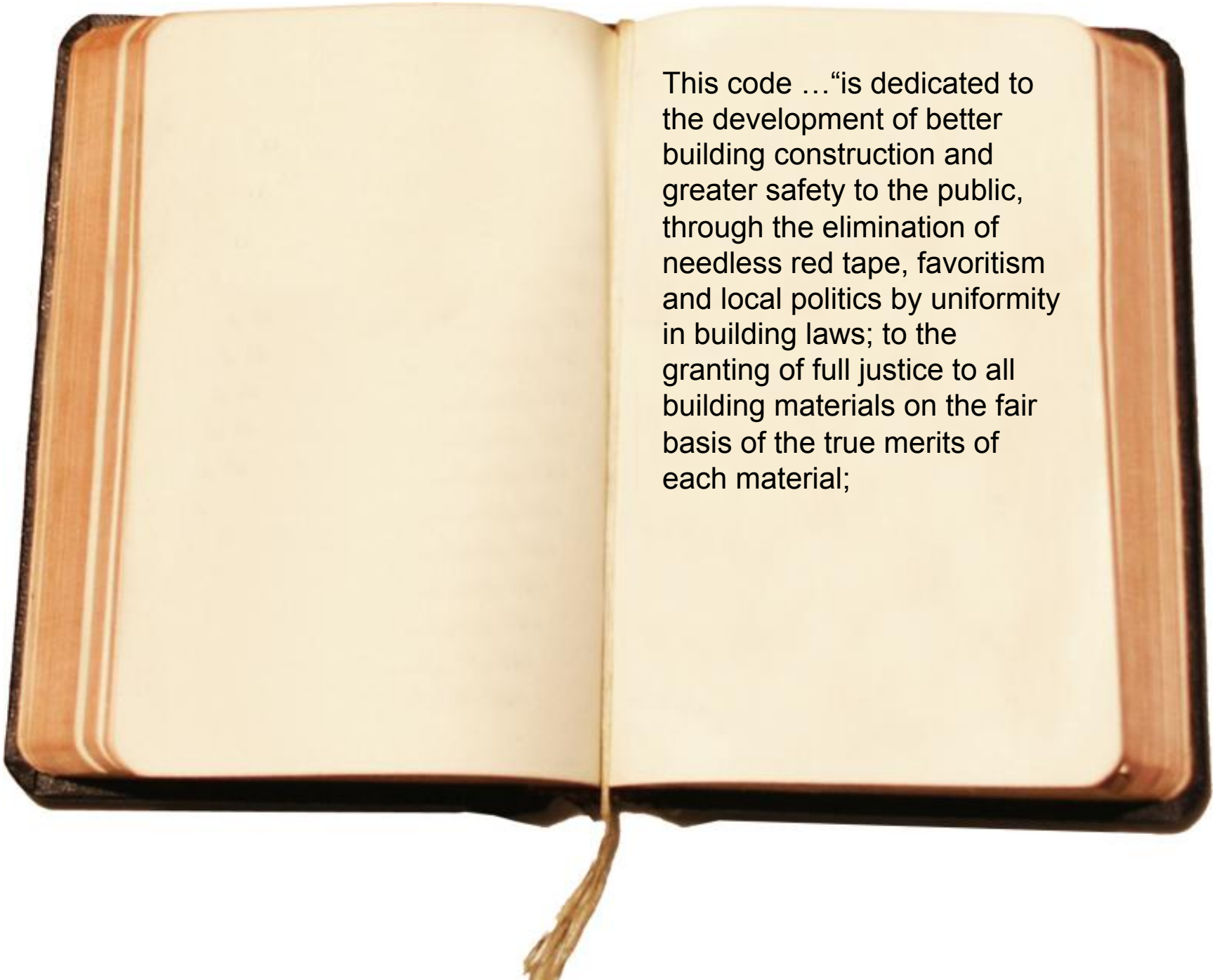
	Core Wall	Dual System	BRBF
Code	$326,000	$323,000	$206,000
TBI Guidelines	$282,000	$269,000	$141,000

- Total Cost = Construction cost + Net present value of insurance premiums

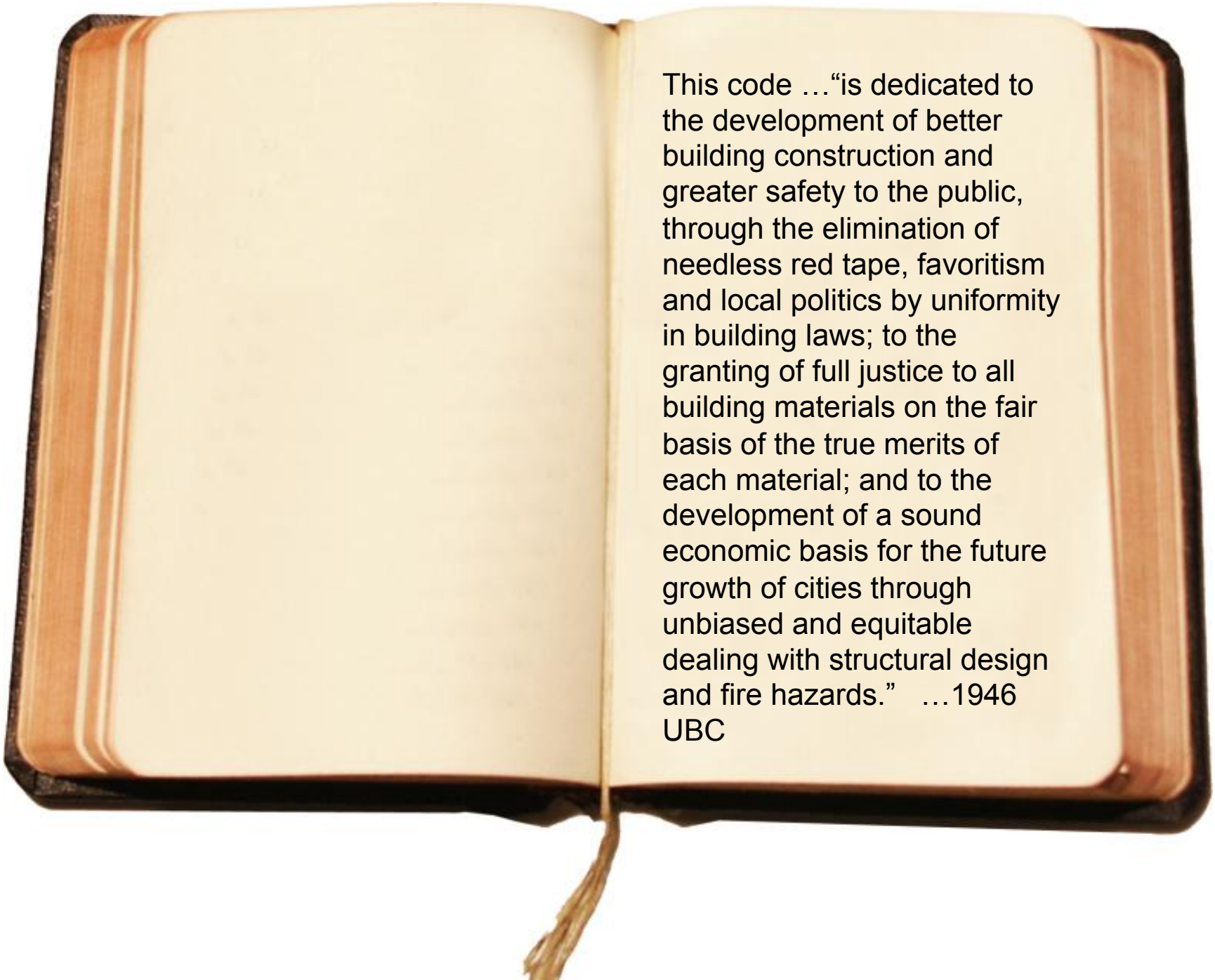
	Core Wall	Dual System	BRBF
Code	$149M	$157M	$346M
TBI Guidelines	$150M	$180M	$337M


The
New
Code


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;



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;



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