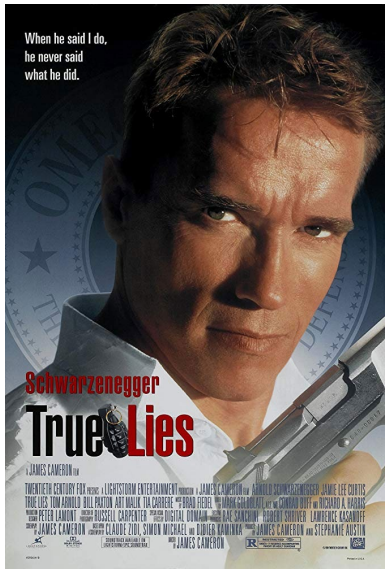
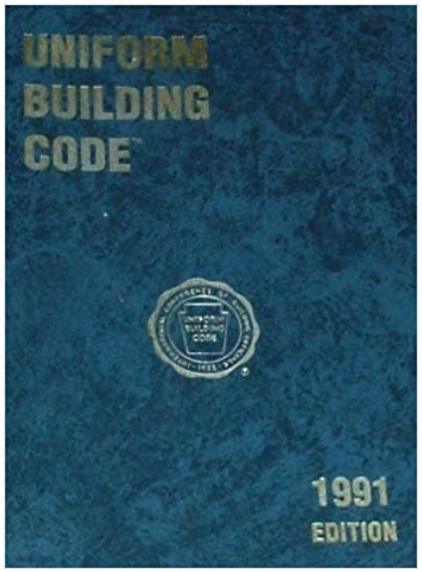
The Northridge Earthquake and Structures

Jack Moehle

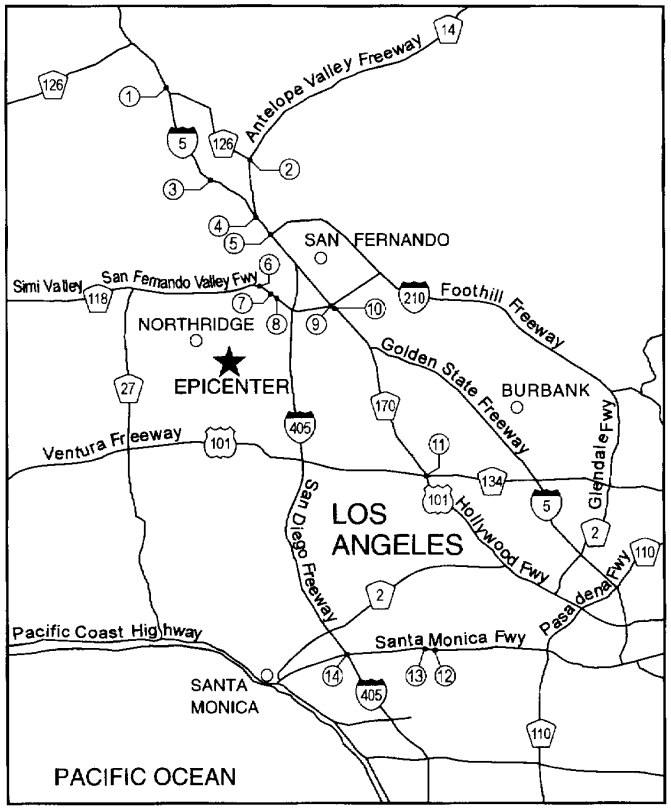
PEER

1994


When he said I do,
he never said
what he did.
Schwarzenegger
True Lies


UNIFORM
BUILDING
CODE
1991
EDITION

Freeway and collapsed or damaged bridge locations



1. Santa Clara River Bridge
2. 126/14 Separation
3. Gavin Canyon Undercrossing
4. 5/14 Interchange
5. 5/210 Interchange
6. Ruffner Avenue Overcrossing
7. Mission-Gothic Undercrossing
8. Bull Creek Canyon Channel UC
9. 5/118 Connector
10. Pacoima Wash Bridge
11. 101/170/134 Separation
12. Fairfax-Washington Undercrossing
13. La Cienega-Venice Undercrossing
14. 10/405 Southwest Connector

Interstate 5/State Road 14 Interchange

EERI (left); Paul Harris, Getty Images

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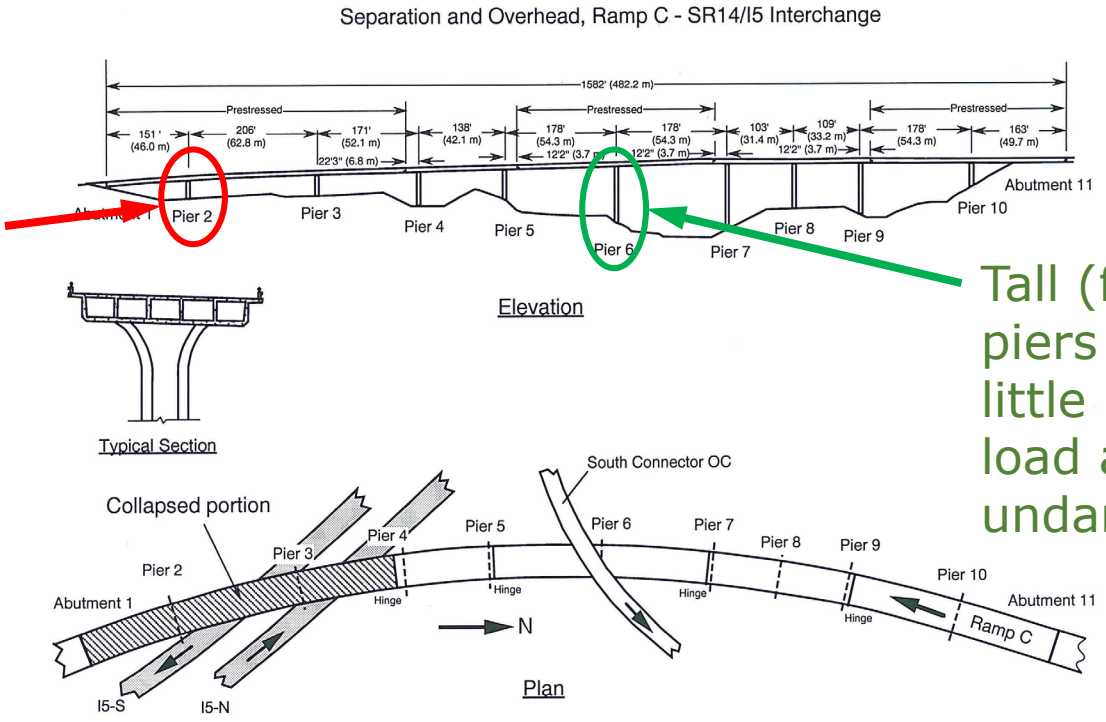
Unbalanced bent stiffness

Short (stiff) piers attracted large lateral force crushing Pier 2 and triggering collapse of 3 spans



Tall (flexible) piers attracted little lateral load and were undamaged

Ian Buckle

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Unexpected plastic hinge locations

Bull Creek Canyon Bridge

SR 118 Mission-Gothic Undercrossing

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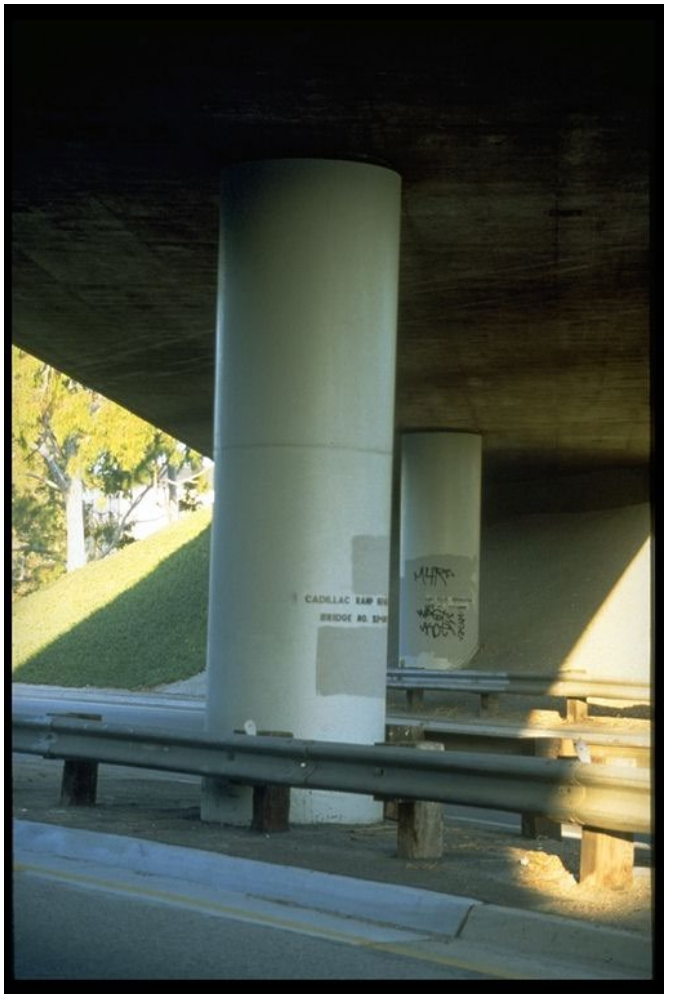
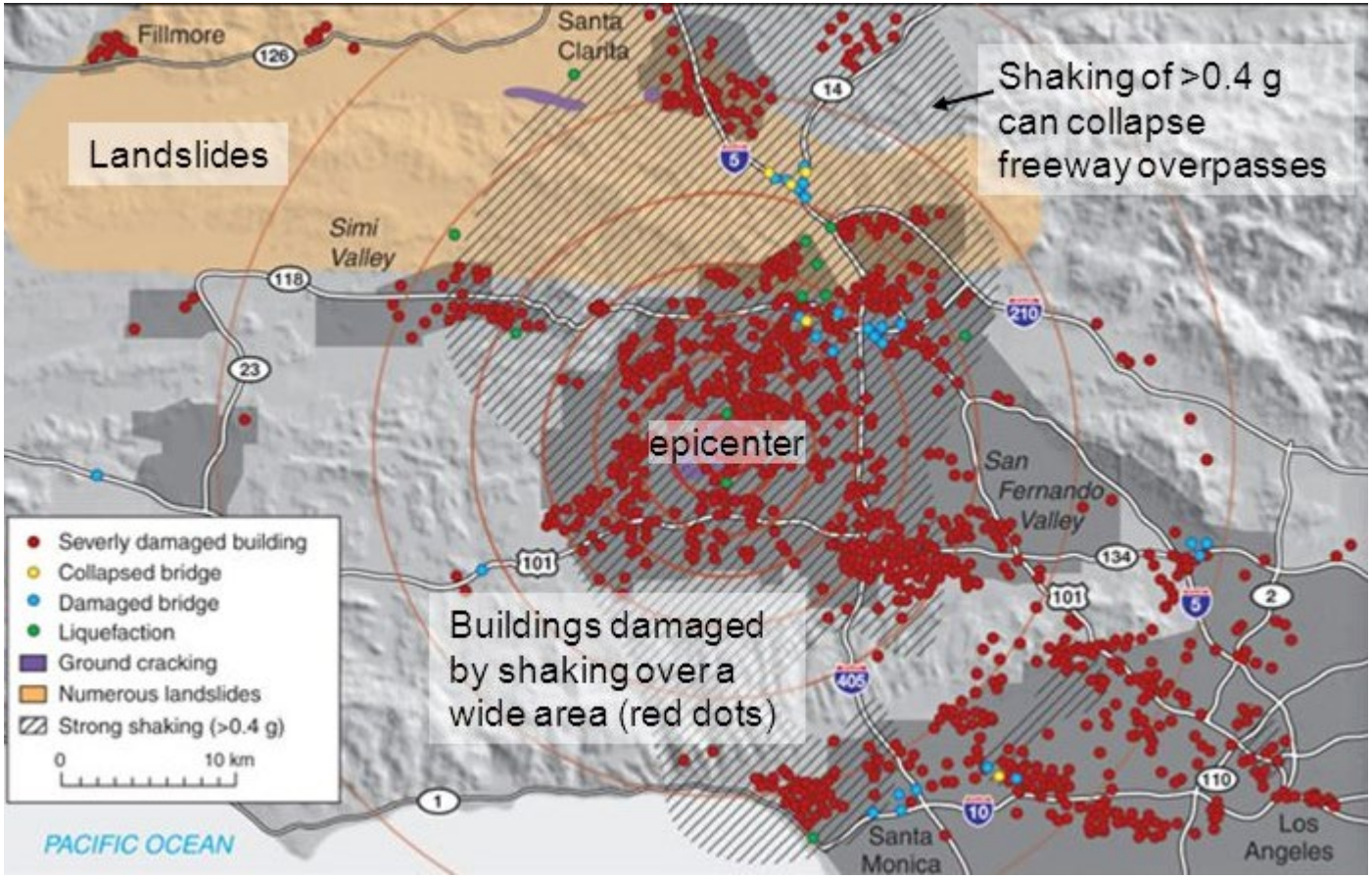
Good performance of jacketed columns



Building damage



USGS

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Older existing concrete

Van Nuys Holiday Inn

Kaiser Permanente

NISEE (left); Visions of America/UIG via Getty Images (right)

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Concrete gravity framing

CSU Northridge Parking Garage

Gene Corley, CTL (left); Peter Weigand, CSU-Northridge (right)

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Concrete diaphragms

Northridge Fashion Center Parking Garage

AP Photo/Reed Saxon

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Rigid Wall Flexible Diaphragms

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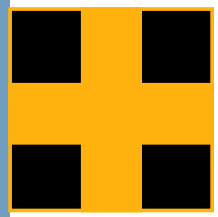
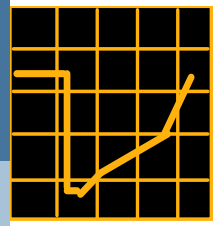
Woodframe buildings



Casualties: 24 of the 25 fatalities in the Northridge Earthquake that were caused by building damage occurred in woodframe buildings (1)

Property Loss: Half or more of the $40 billion in property damage was due to damage to wood buildings; approximately. $15 billion in insured loss (2)



Functionality: 48,000 housing units, almost all of them in woodframe buildings, were rendered uninhabitable by the earthquake (3)

(1) EQE and Calif. OES, 1995
(2) Charles Kircher et al., 1997, and Robert Reitherman, 1998
(3) Jeanne B. Perkins, et al., 1998

Multi-family residential woodframe buildings with weak/soft stories

Hillside homes

City of Los Angeles Department of Building and Safety

PEER

Unbraced or unbolted cripple walls

Ron Gallagher

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Nonstructural/Hospitals

Olive View Hospital 1971

Olive View Hospital 1994

1973 Hospital Seismic Safety Act

Requires hospitals to be designed and constructed to withstand a major earthquake and remain operational

Maryann Phipps

PEER

Performance of all buildings at 23 hospital sites

	Number (%) of Buildings	
Type of Damage	**Pre Act**	**Post Act**
Structural Damage		
Red Tagged	12 (24%)	0 (0%)
Yellow Tagged	17 (33%)	1 (3%)
Green Tagged	22 (43%)	30 (97%)

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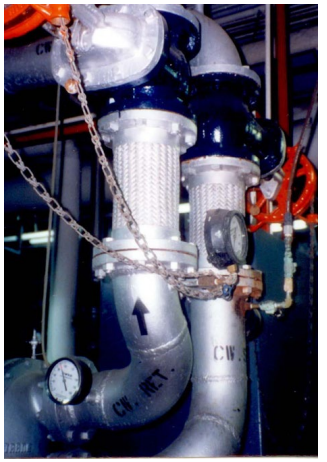
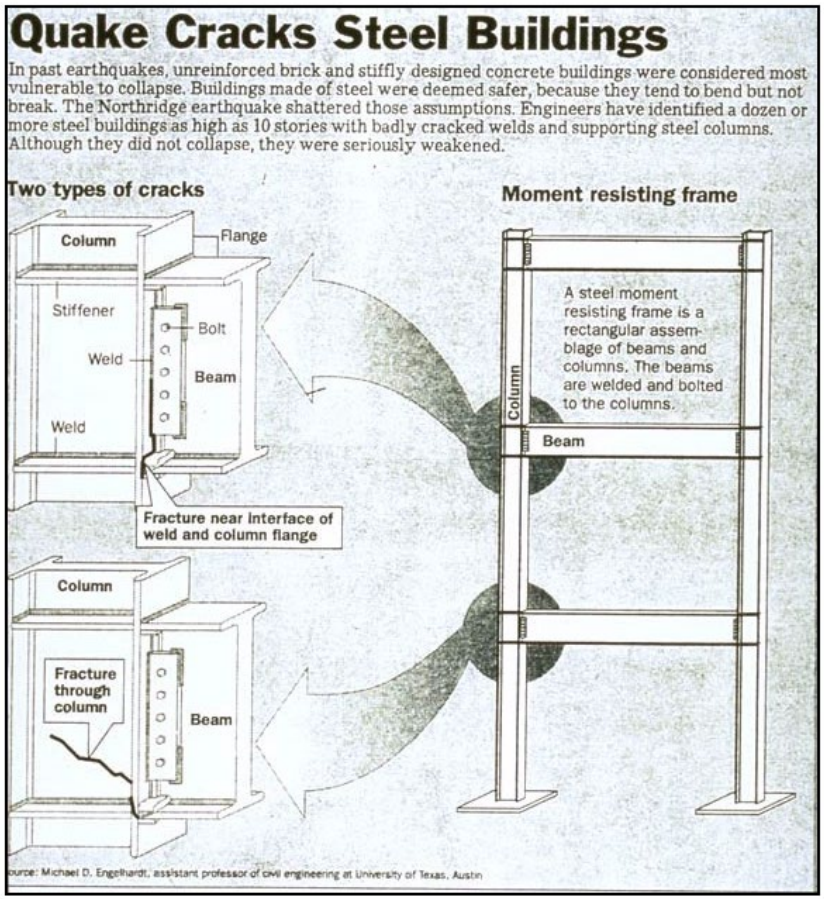
Nonstructural Damage		
Major	31 (61%)	7 (23%)
Minor	20 (39%)	24 (77%)
Total Buildings	51	31

Increased focus on nonstructural + SB1953



Steel buildings



LA Times (left); EERI (right)

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Steel buildings

Beam flange

Column web

Base plate

The SAC Steel Project

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Codes for steel seismic design

- Before Northridge – ’85 UBC
  - Ductile Moment Frames covered in one page
  - Those were the days!
- Steel Moment Frames in ’92 AISC Seismic
  - 4 ½ pages total
  - Pre-qualified what came to be known as the “Pre-Northridge” Connection
- AISC 341-10
  - 20 pages of Moment Frame Requirements
  - AISC 341-10 is 356 pages, including Commentary
  - AISC 358-10 (Pre-qualified connections standard) is another 157 pages
  - AWS D1.8 (Seismic Supplement to D1.1) is another is another 111 pages

1994 - Historic Context

PBD for Existing Buildings

- ATC 33 (ASCE 41)

PBD for New Buildings

- FEMA action plan
- SEAOC Vision 2000

SEAOC Seismology converting UBC to strength basis

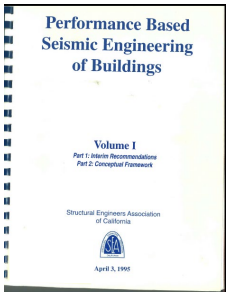
AISC struggling with dual-certified steel

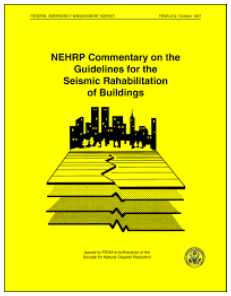
Ron Hamburger

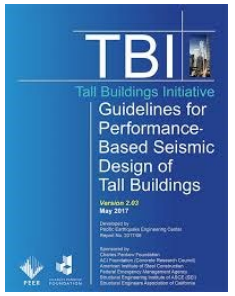
PEER

Major Impacts of Northridge EQ

- Scope of UBC strength conversion expanded
  - Redundancy
  - Rigid-wall flexible diaphragm wall anchorage force increase
  - Near-fault Seismic Design Categories established
  - Spectral shape and base-shear limit for long-period motion (velocity pulses)
  - Prohibition in extreme soft/weak stories, torsional irregularities
- FEMA/SAC Project
  - Revamp of AISC 341
  - Introduction of AISC 358, AWS D1.8
  - Use of reliability-based approaches to establish design criteria
- Performance-based design
  - Vision 2000
  - ATC 33 (ASCE 41)
  - FEMA P695
  - PEER focus on PBD
  - ATC-58 Project
  - TBI Guidelines







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Thanks to …

Ian Buckle
Bridges and Transportation

SK Ghosh
Concrete Structures

Kelly Cobeen
Woodframe Structures

William Holmes
Existing Buildings

James Malley
Steel Structures

Maryann Phipps
Nonstructural/ Hospitals

Ron Hamburger
Codes and PBEE