NORTHRIDGE 20
SYMPOSIUM

Innovative Column Designs

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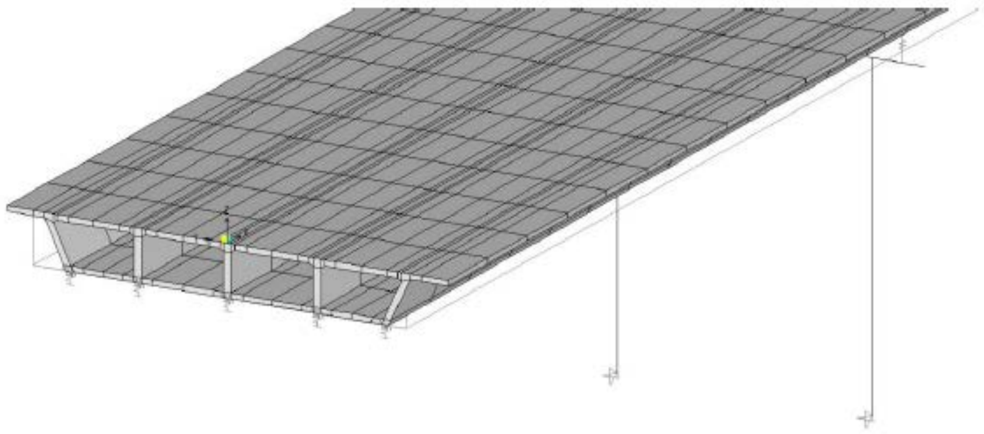
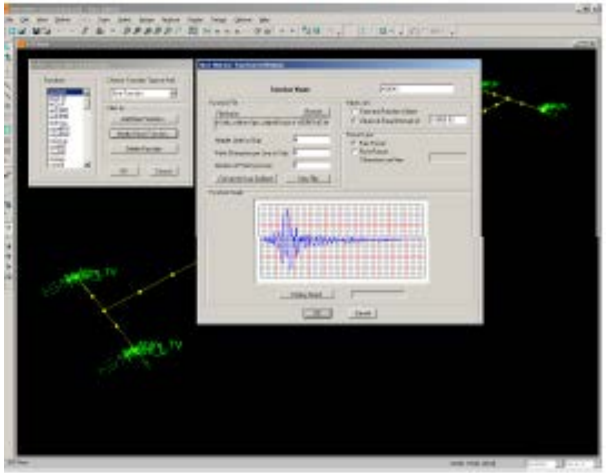
Progress in Bridge Design

- Design and Assessment Methodologies
  - Displacement-based design
  - Nonlinear analysis
  - Estimates of deformation capacities
  - Estimates of shear capacities
  - Software



(Caltrans BDP 2012)



(Aviram 2008)

Reinforced Concrete Columns

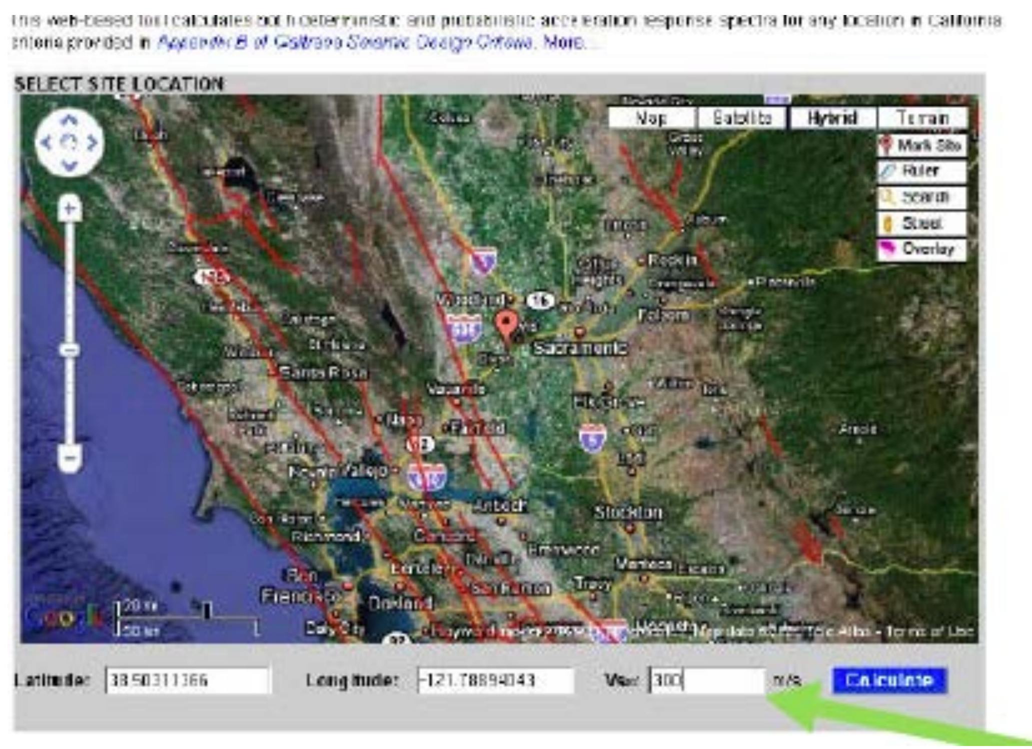
- Column and beam construction type has changed little since mid-1970s
- Cast-in-place columns and beams
  - Build reinforcing cage
  - Place forms
  - Install shoring
  - Cast concrete
  - Wait to gain strengt
  - Repeat….
- Time Consuming!

(www.southbayexpressway.com)

Construction is Disruptive Too!

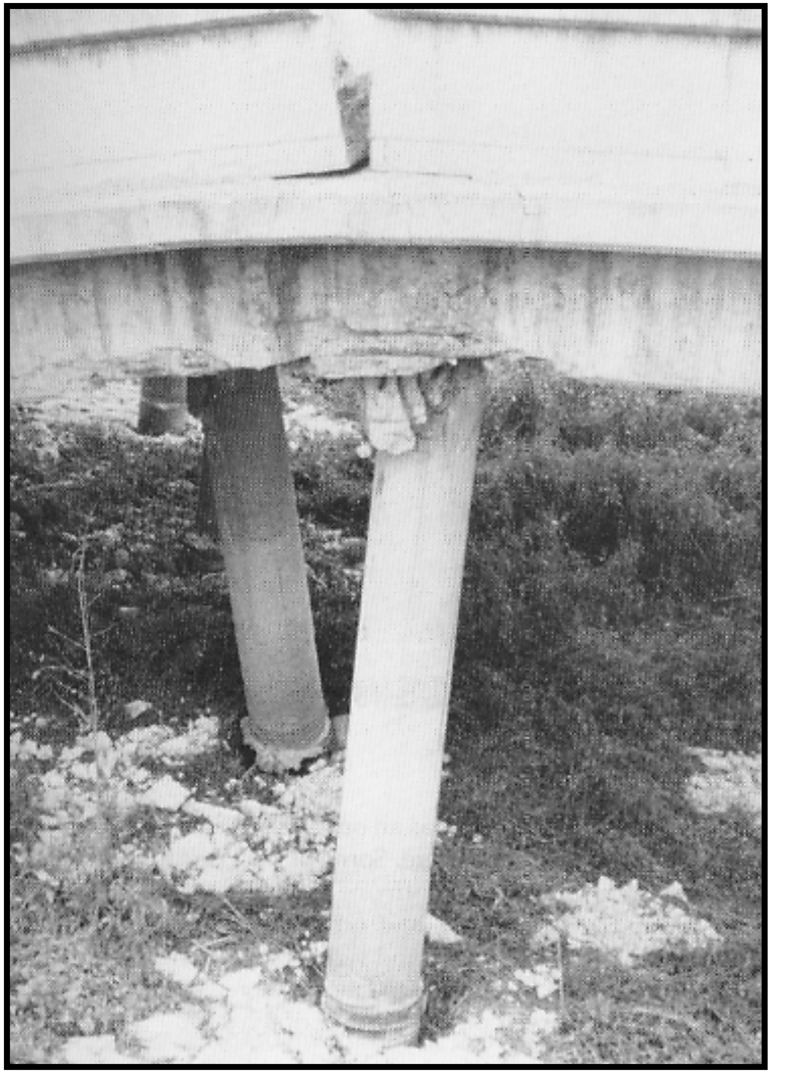
Progress in Bridge Design

- Characterization of Ground Motions
  - Detailed, consistent intensity maps
  - Fault characterization
  - Local site amplification
  - Liquefaction



(Shantz, Merriam 2009)

Damage Costly and Disruptive



Safety During Extreme Events



Resilient Bridges

- Decreased Column Damage
- Improved Recentering
- Safe Even During Extreme Earthquakes
- Less Traffic Disruption During Construction

Materials

- Hybrid fiber reinforced concrete
- Engineered cemetitious composites
- Steel shell / corrugated pipe
- Stainless steel reinforcement
- Shape memory alloys
- Headed reinforcement

Prestressing

Pre-tensioning with partially unbonded strands

Post-tensioning with unbonded tendons
(Sakai and Mahin 2003)

Post-tensioning with threaded bars

Prefabrication

Courtesy of Concrete Technology Corp.

PEER Innovative Column Project

- Three new column designs
- One conventional column
- Cantilevered columns

  $M/(V \times D) = 6$

- Tri-axial input motions on PEER's Earthquake Simulator at UC Berkeley
- Similar ground motions

Column Concepts

Conventional RC Column

- *Benchmark test*
- *Designed per Caltrans SDC v1.6*
- *A706 reinforcement*

(UC Berkeley)

Column Concepts

Conventional RC Column	***Precast/Pre-tensioned Column***
• *Benchmark test* • *Designed per Caltrans SDC v1.6* • *A706 reinforcement* (UC Berkeley)	• *Precast* • *Pre-tensioned* • *HyFRC shell in plastic hinge* • *Headed bars* (Univ. of Washington)
	

Column Concepts

Conventional RC Column

- *Benchmark test*
- *Designed per Caltrans SDC v1.6*
- *A706 reinforcement*

(UC Berkeley)

Precast/Pre-tensioned Column

- *Precast*
- *Pre-tensioned*
- *HyFRC shell in plastic hinge*
- *Headed bars*

(Univ. of Washington)

HyFRC Column

- *Post-tensioned*
- *Precast HyFRC block at base*
- *Rocking column*
- *Headed bars*

(UC Berkeley)

Column Concepts

Conventional RC Column

- *Benchmark test*
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(UC Berkeley)

Precast/Pre-tensioned Column

- *Precast*
- *Pre-tensioned*
- *HyFRC shell in plastic hinge*
- *Headed bars*

(Univ. of Washington)

HyFRC Column

- *Post-tensioned*
- *Precast HyFRC block at base*
- *Rocking column*
- *Headed bars*

(UC Berkeley)

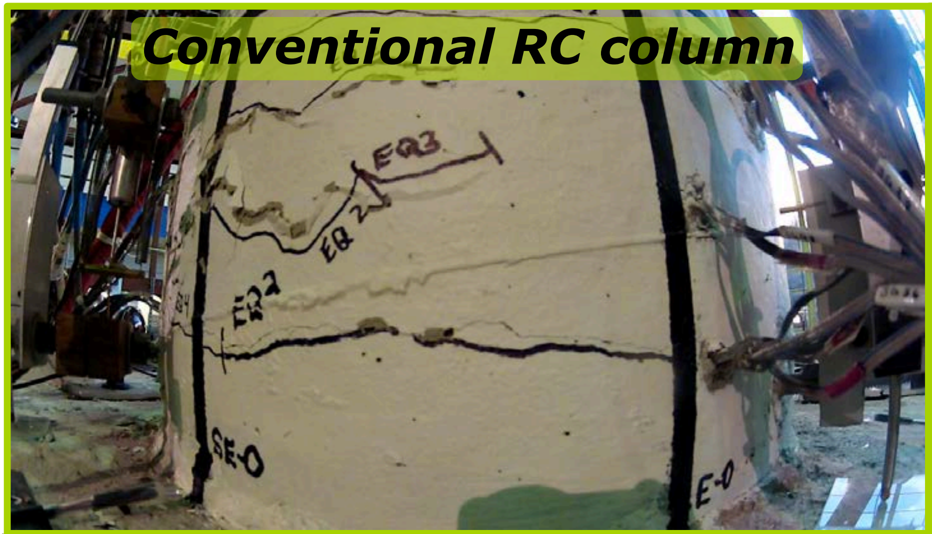
Dual Steel Shell Column

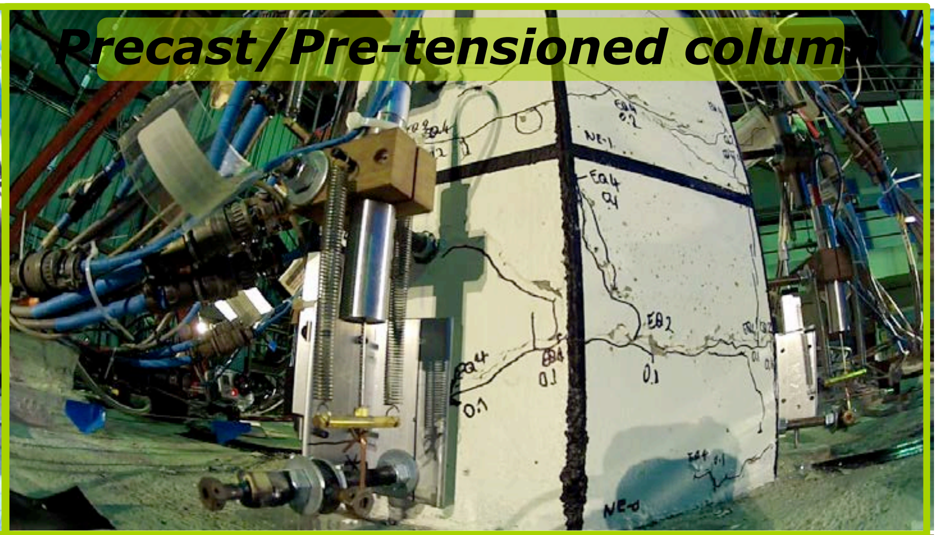
- *Post-tensioned*
- *Hollow inner shell*
- *Stainless steel reinforcemen*
- *Headed bars*
- *Rocking column*

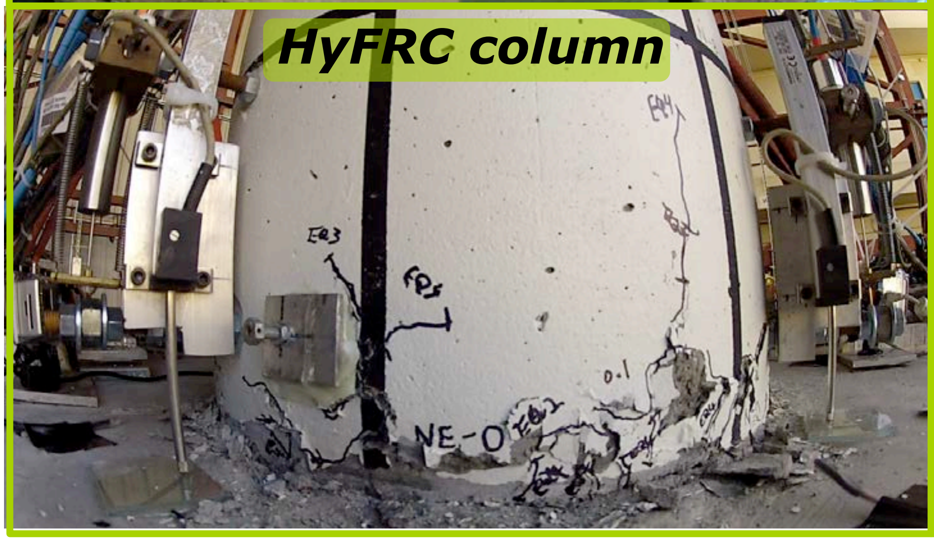
(UC San Diego)

Shake Table Testing

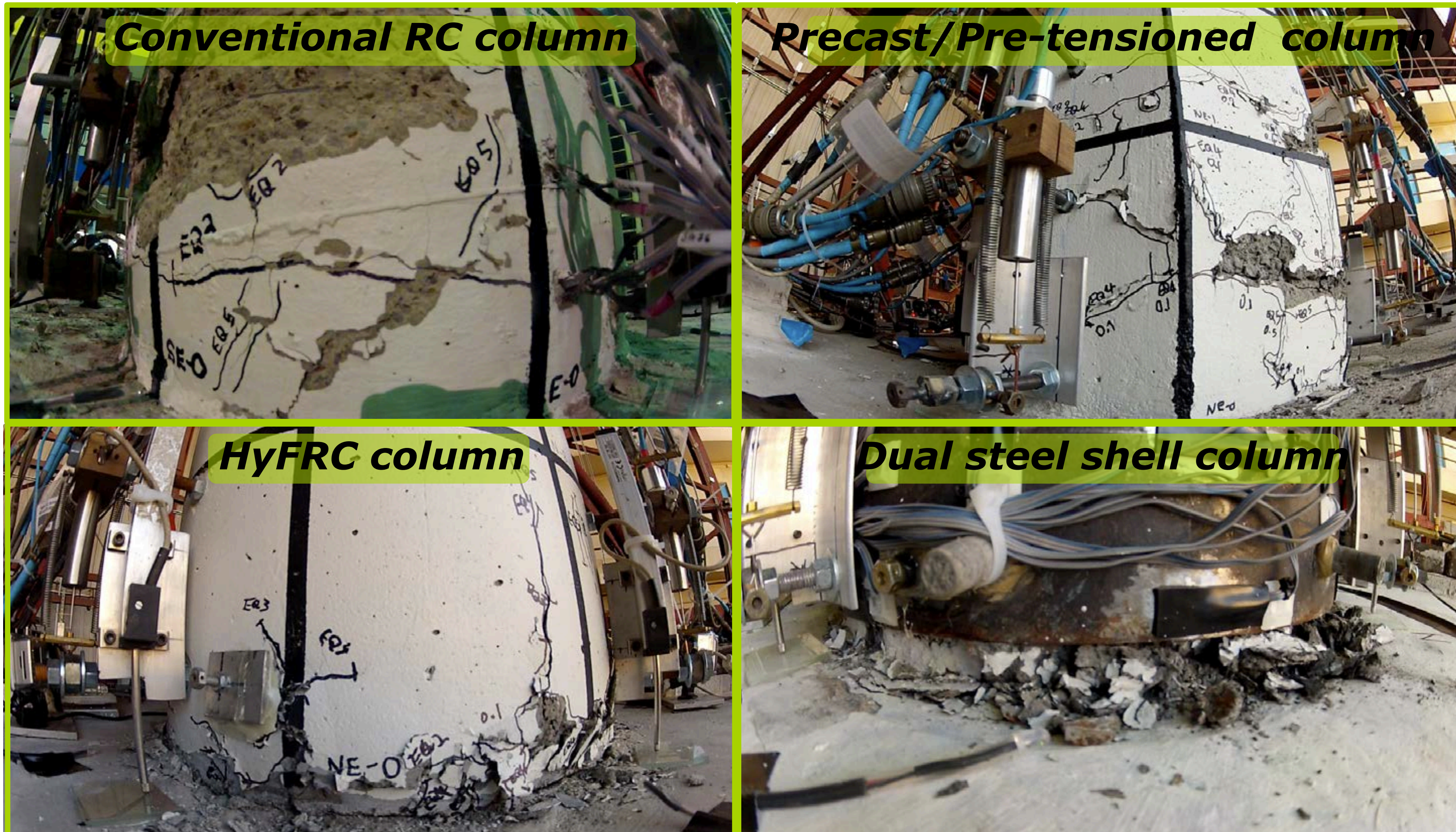
Damage: Design Level



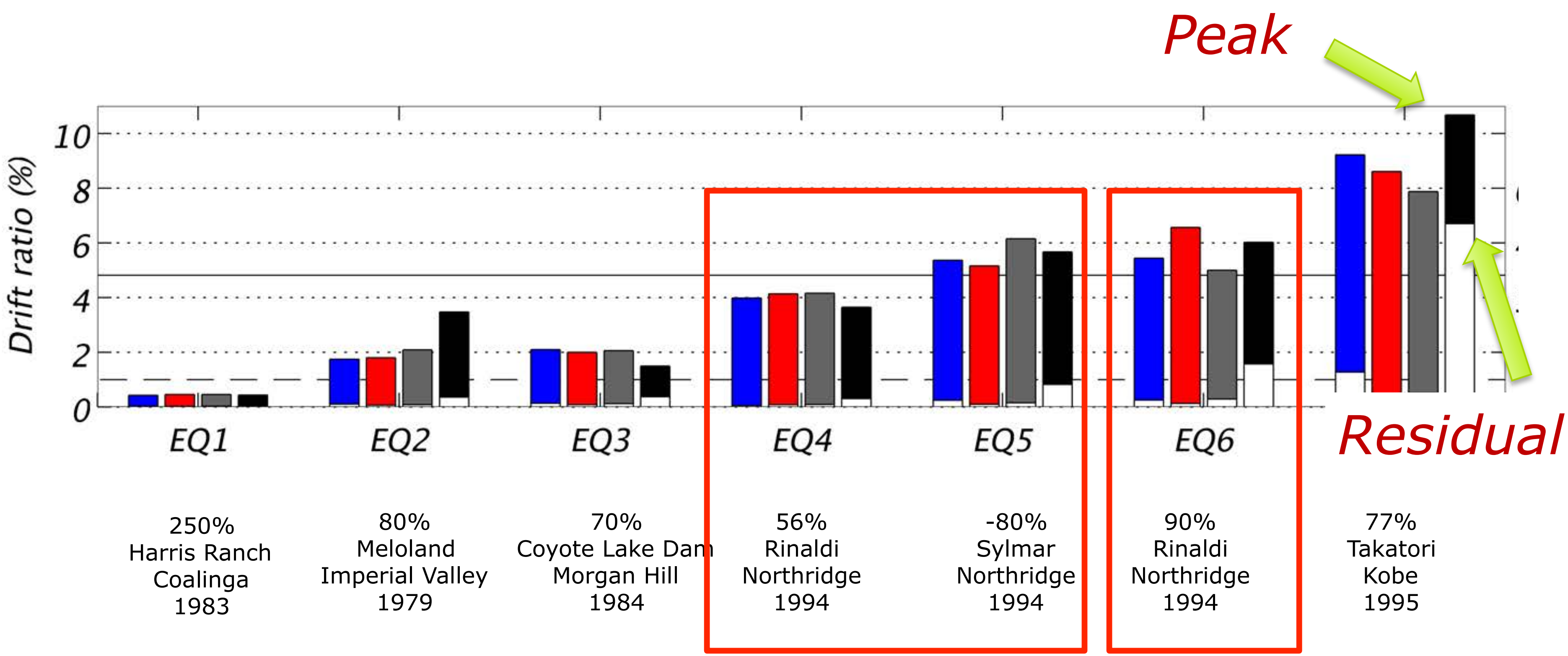




Damage: 1.5x Design



Residual Displacements



Design Level 1.5x Design Level

Safety

77% of Takatori Record

1995 Kobe Earthquake


PEER BERKELEY

Conclusions

- New materials, prestressing and prefabrication can improve column resiliency.
- Can increase speed of construction and seismic performance simultaneously.
- Damage Reduction
  - Low damage during design event for all columns
  - New columns reduced damage for large events
- Unbonded prestressing effective in reducing residual displacements
- All proposed columns would likely be safer during extreme events

Looking Forward: Needs

- Detail modifications to further reduce damage
- Specific performance goals
- Cost-benefit analyses over life of bridge
- Consideration of system performance
- Familiarize EQ community with new systems

Participants

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Hammad El Jisr (PEER Intern)

Caltrans

THE CONCO COMPANIES CONCO

CONCRETE TECHNOLOGY CORPORATION

SWPC

DSI

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Questions?