Retrofit of an Existing Hospital to Immediate Occupancy Standards

One Year Later

- **Degenkolb Engineers**

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Damaged Hospital Building

- Designed in 1974 to Hospital Act requirements
  - Importance factor = 1.5
- Two stories plus basement
- "Gateway" to the Hospital + Emergency Department
  - Radiology, MRI, CT Scan
  - Surgery
  - Cath Lab
  - G.I. Laboratory
  - Materials Management/ Medical Supplies

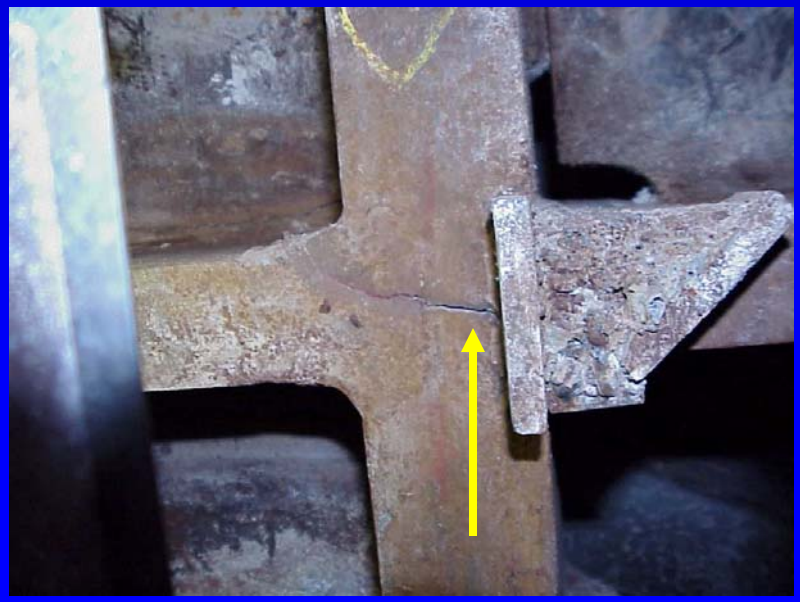
Policy Issues

- Code
- Title 24 – California Building Code requires the building be improved to meet current code performance requirements
  - Goal - Immediate Occupancy performance
- Funding
  - Approach meets FEMA requirements for hazard mitigation

Connection Damage

- Discovered as part of SB 1953 Structural Evaluation – April 2000
  - 1st floor – 1 connection in N-S frame
  - 2nd floor – 7 connections (6 in N-S frames)
  - Roof – 6 connections (5 in N-S frames)
- Five of connections – cracks across the column section
- Repair procedures approved by OSHPD in July
- Repairs around the clock for 6 months in an operational hospital building

Column Damage- Flange & Webs



Structural Issues

- Steel Moment Resisting Frames in both directions above grade
  - Strong Beam – Weak Column
  - Damaged SMRF connections
  - Brittle column steel

Structural Approach

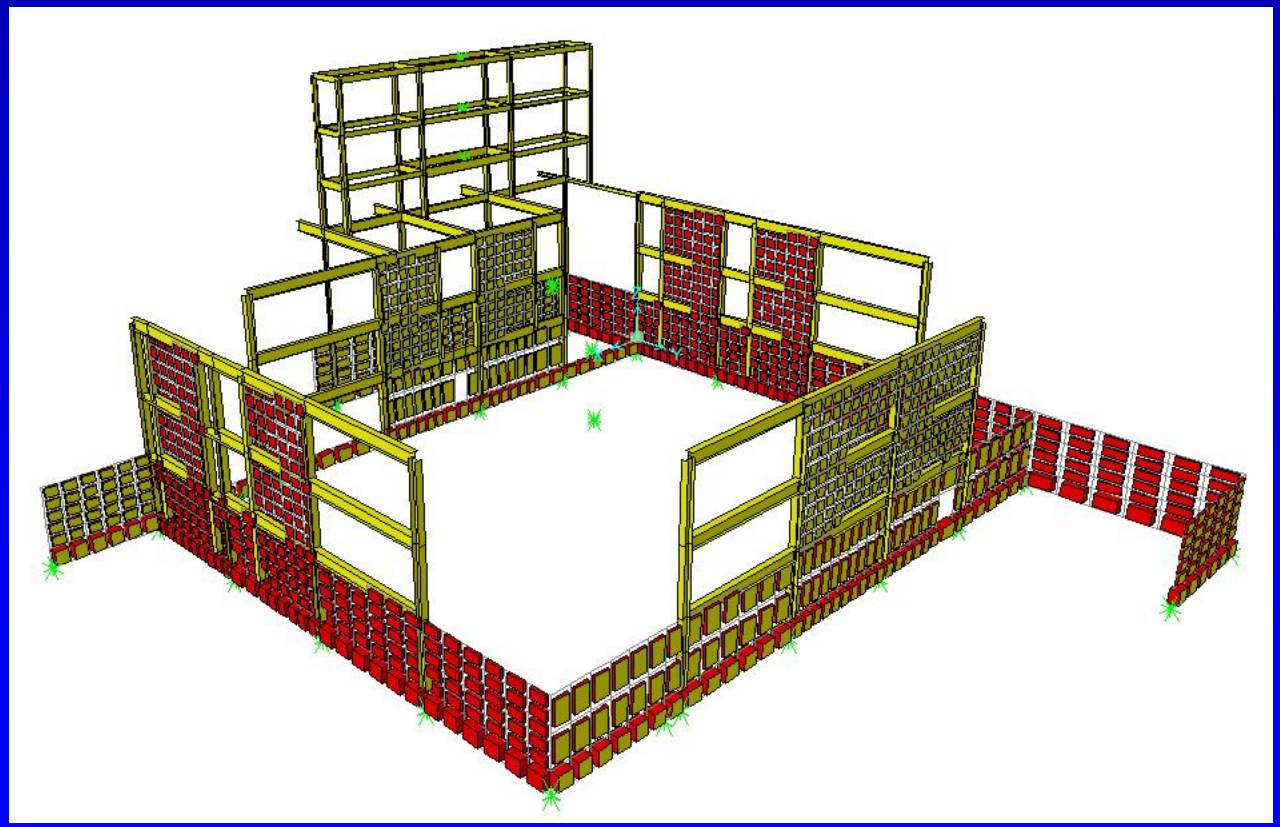
- Modify the lateral system from SMRF to Steel Plate Shear Wall (SPSW)
  - Adds strength
  - Adds stiffness
  - Focuses tension yielding / plate buckling in steel plate

Progress

- Revised Foundation design criteria
  - Additional soils information
- Nonstructural Bracing Criteria
  - Development and approval of NPC bracing criteria based on successful past performance during Northridge EQ
- Modal Response Analysis
- Nonlinear Static Pushover Analysis
- Nonlinear Time-history Analysis
- OSHPD Plan Review in progress

Linear Elastic Analysis model with Finite Elements

- Used for basement and foundation design



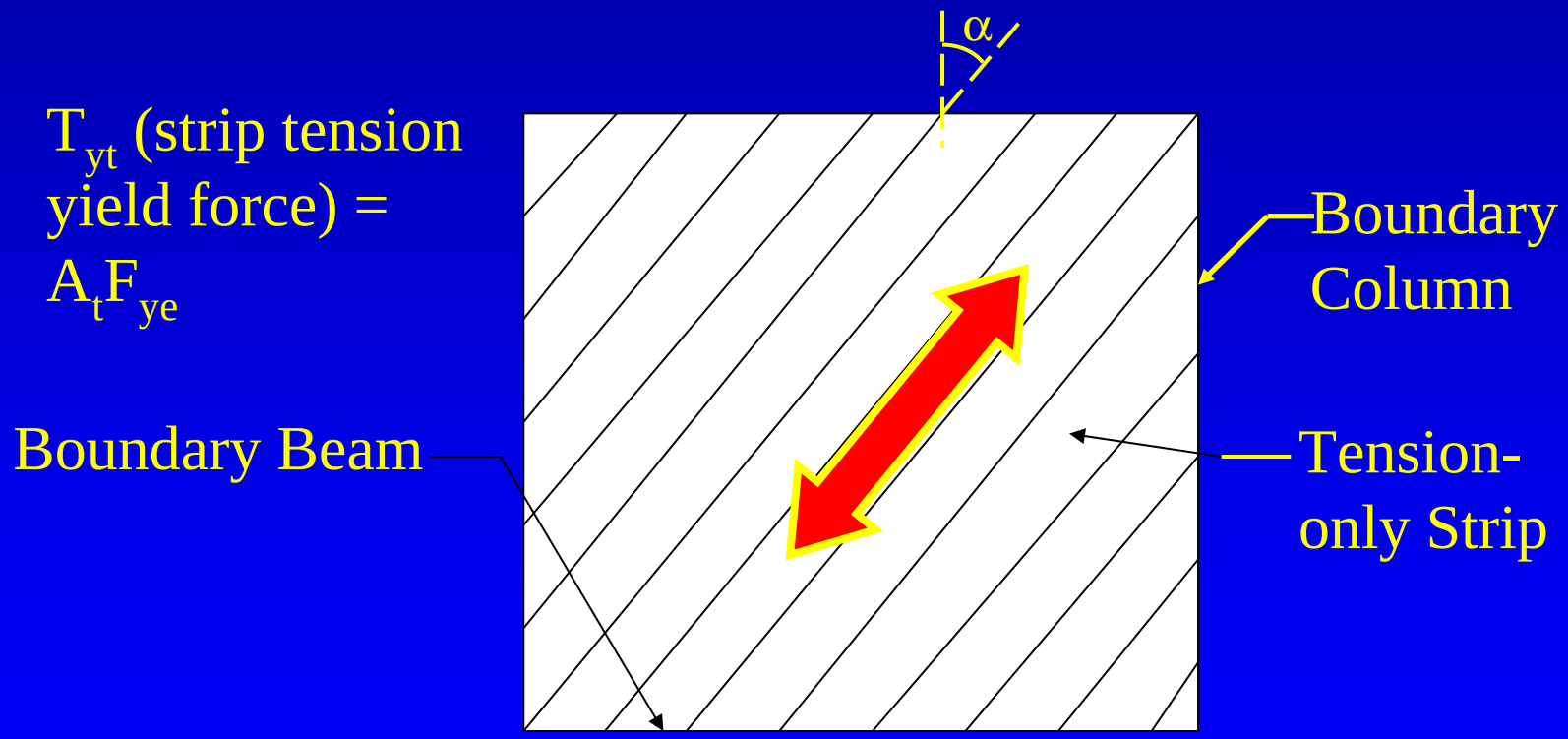
Maximum Allowable Drift Ratios

- Immediate Occupancy – 0.012
  - CBC allows 0.025 for T<0.7 seconds for new buildings
- Collapse Prevention – 0.020

Superstructure Analysis - Steel Plate Walls + Frame Analysis

- Non-linear Static Pushover
  - Target Displacement at DBE
  - SAP 2000 analysis
- Non-linear Time History Analysis
  - maximum interstory drifts
  - 3 pairs of time histories required
  - Ram Perform 3-D

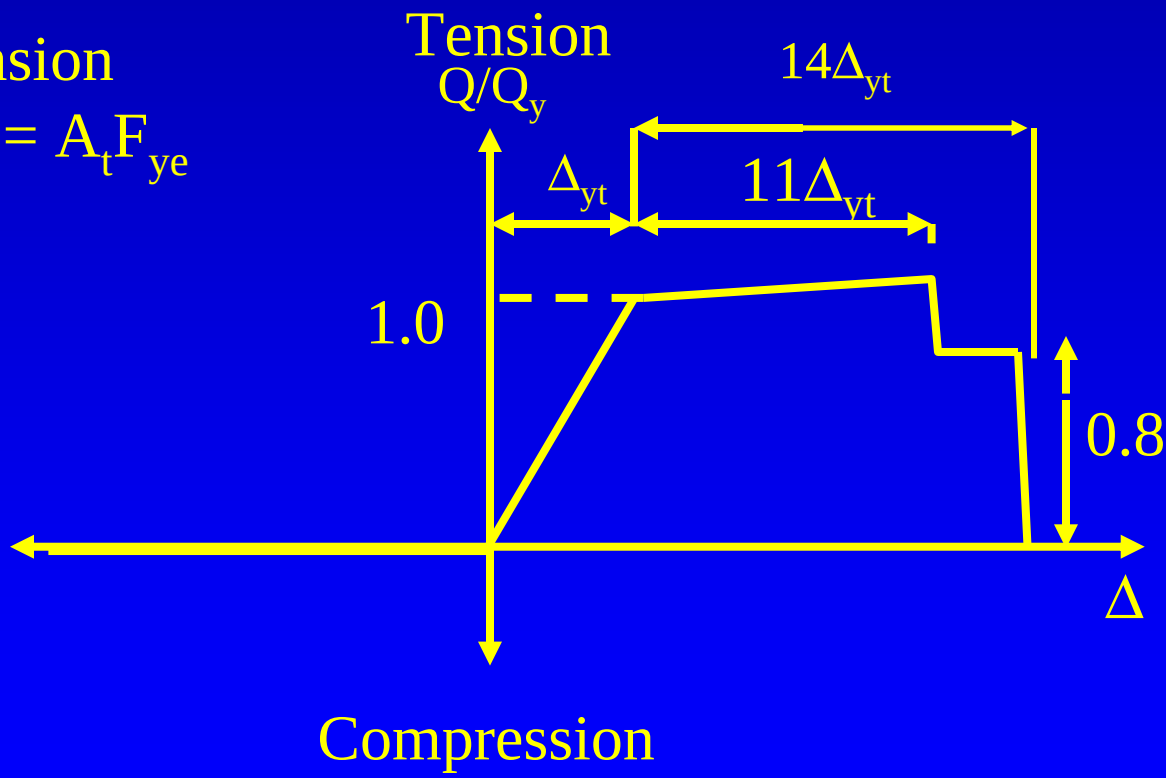
Steel Plate Wall Analysis – Nonlinear Pushover Model



Steel Plate Shear Wall Tension Strip Model

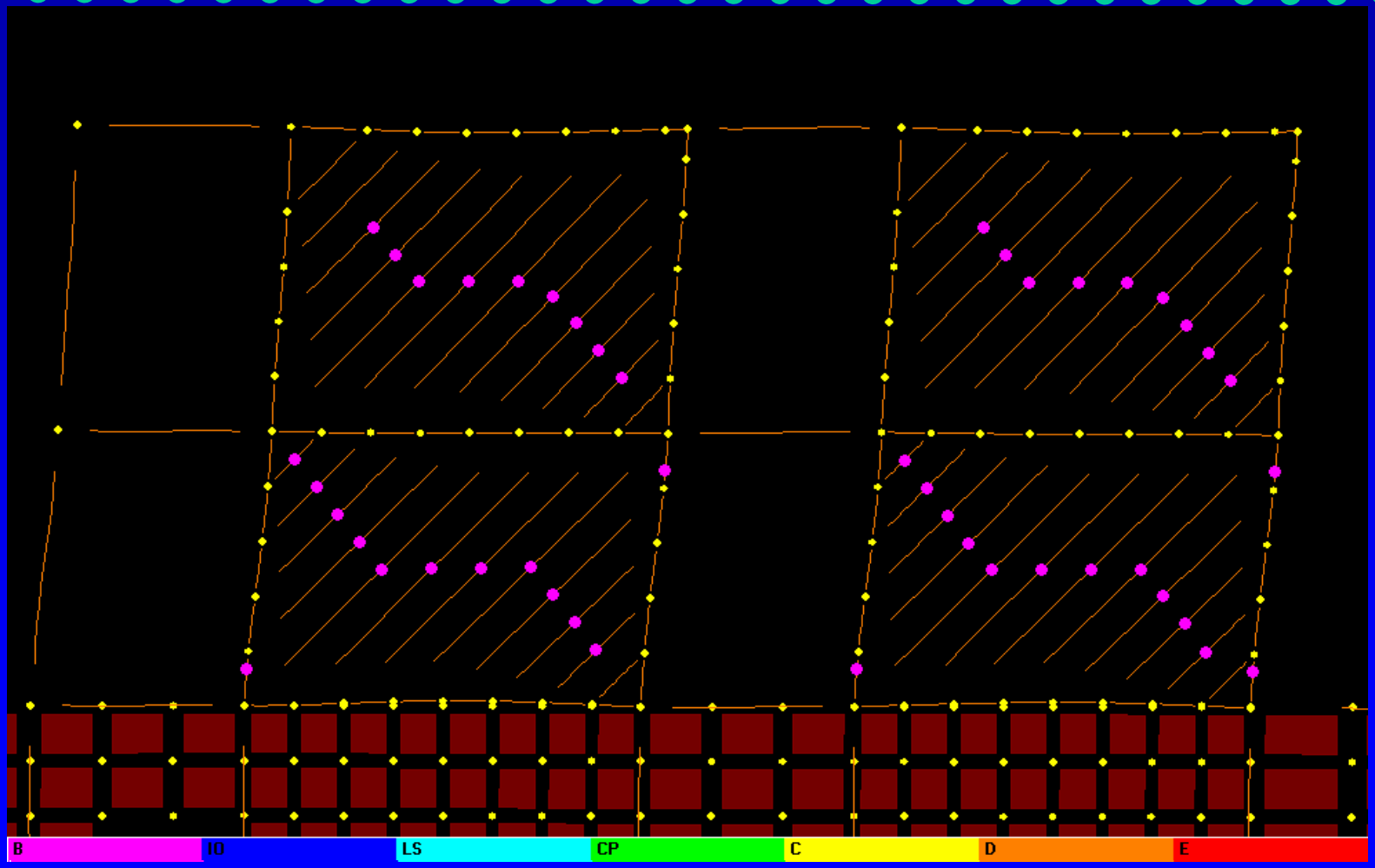
Steel Plate Wall Analysis

T_{yt} (strip tension yield force) = $A_t F_{ye}$

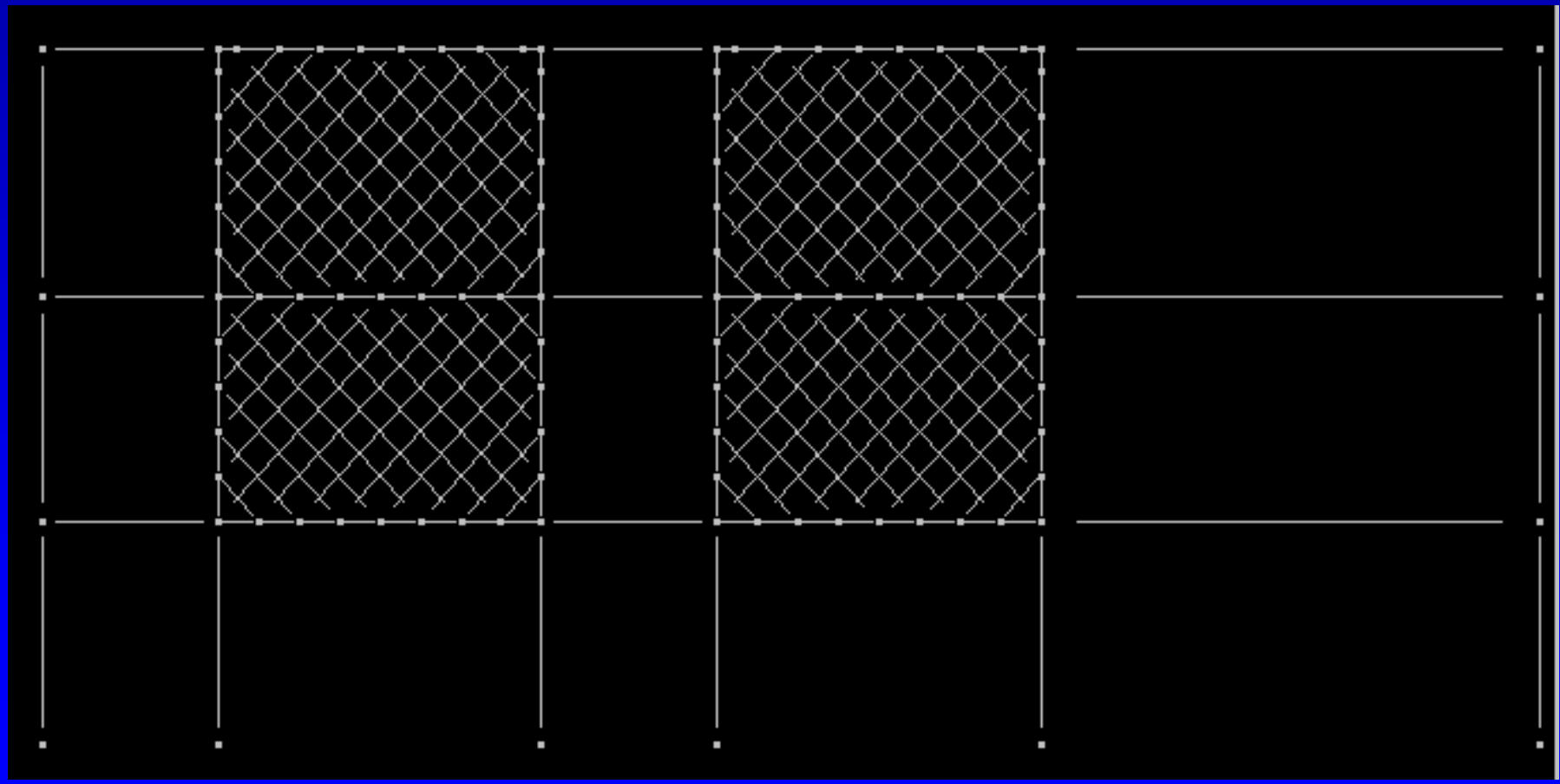


Steel Plate Shear Wall Tension Strip Model

Pushover Yielding Sequence



Steel Plate Strip Model – Time History Model

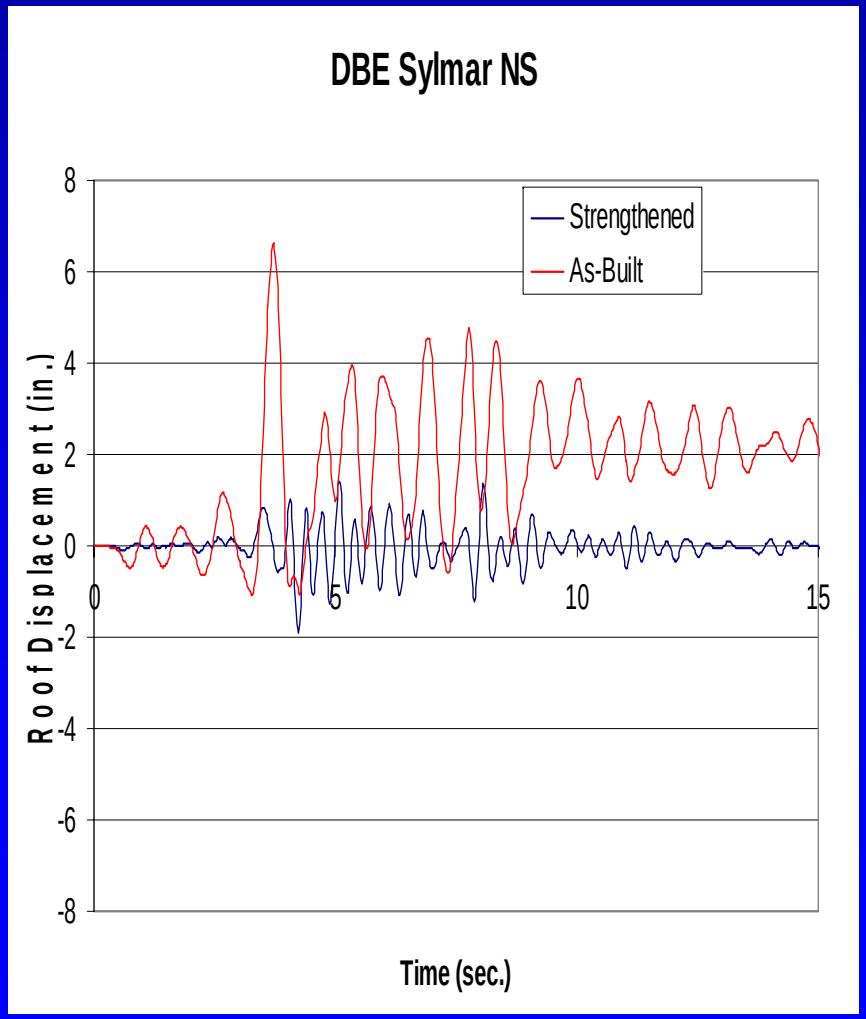


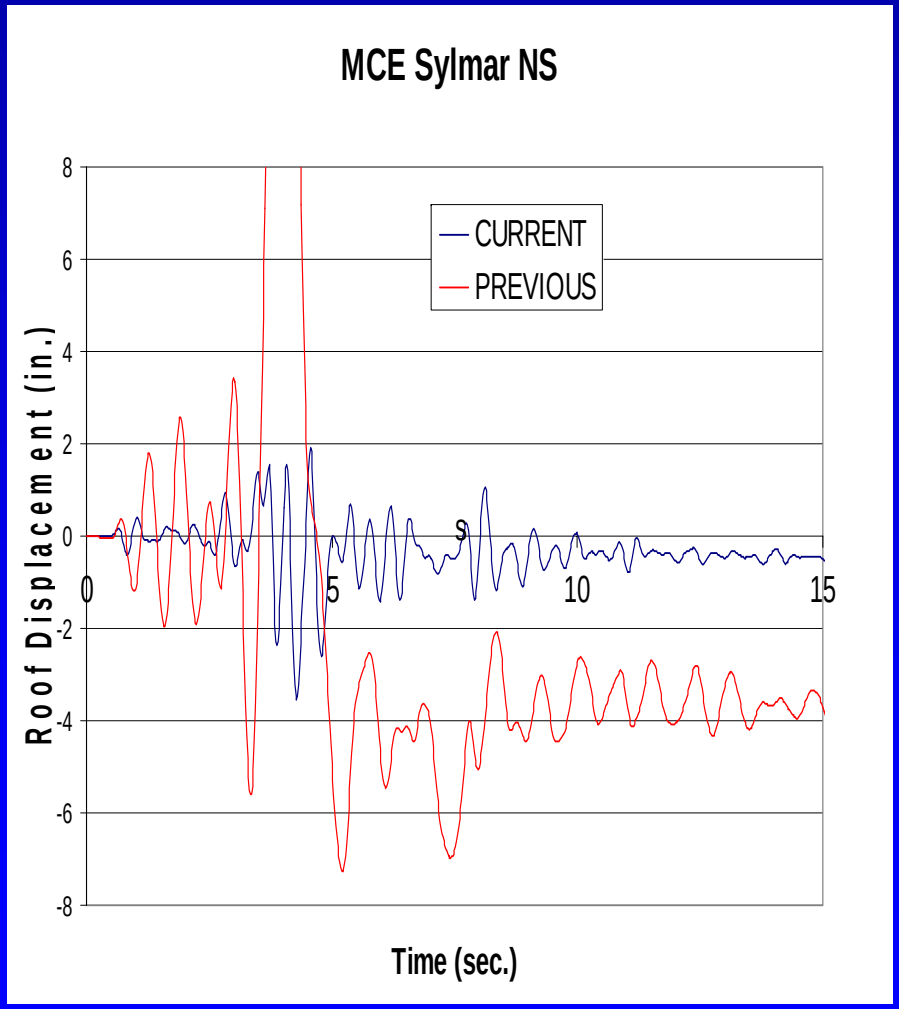
Time History Design Ground Motions

- Design Basis Earthquake
- Maximum Credible

- Sylmar
- Newhall
- El Centro

Nonlinear Time History Results





Maximum Roof Displacement of Strengthened Building

East – West Response

	DBE	MCE
Sylmar NS	1.9”	3.5”
Sylmar EW	1.7”	2.9”
Newhall N46E	1.9”	3.2”
Newhall N44W	1.8”	3.2”
El Centro S50W	1.7”	3.1”
El Centro S40E	1.8”	3.0”

EERI Spectra Journal Article

- "Case Study of a Northridge Welded Steel Moment-Frame Building Having Severed Columns"
  - Bruce Maison, Tom Hale (Vol. 20, Number 3, Aug.-2004)
  - Connections modeled with probabilistic fracturing element
  - Concludes 99% confidence against global collapse for a second event with pre-existing fractured connections
    - FEMA 351 Approach

Challenging Issues Remain

- What does it mean to meet “immediate occupancy”?
  - What level of structural damage causes a hospital to lose its immediate occupancy status?
    - Do we have to meet “current code” to achieve immediate occupancy?
    - How much and what type of structural damage can we allow and still provide immediate occupancy?
      - Foundations
      - Structural steel

Challenging Issues

- Funding Issues
  - How much money should we spend to achieve this goal?
  - Should the age, or expected remaining life, of the building enter into the consideration?
  - Should there be a cap on costs to meet immediate occupancy requirements?
    - Similar to ADA compliance costs?