NORTHRIDGE 20
SYMPOSIUM

Northridge Earthquake 1994-2014

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January 16-17, 2014 - University of California, Los Angeles

Northridge Earthquake 1994 – 2014 Symposium

NORTHRIDGE 20
SYMPOSIUM

Chile: 2010 Earthquake

REPAIR OF 18-STORY SHEAR WALL BUILDING DAMAGED IN 2010 CHILE EARTHQUAKE

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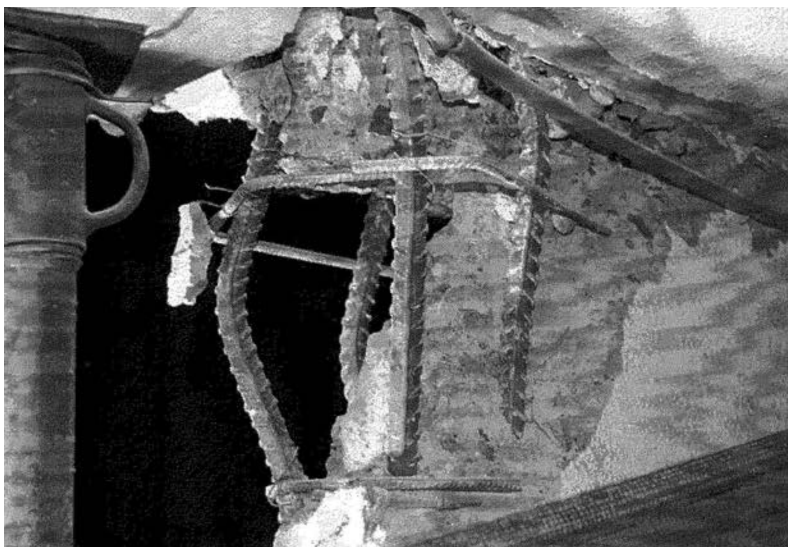
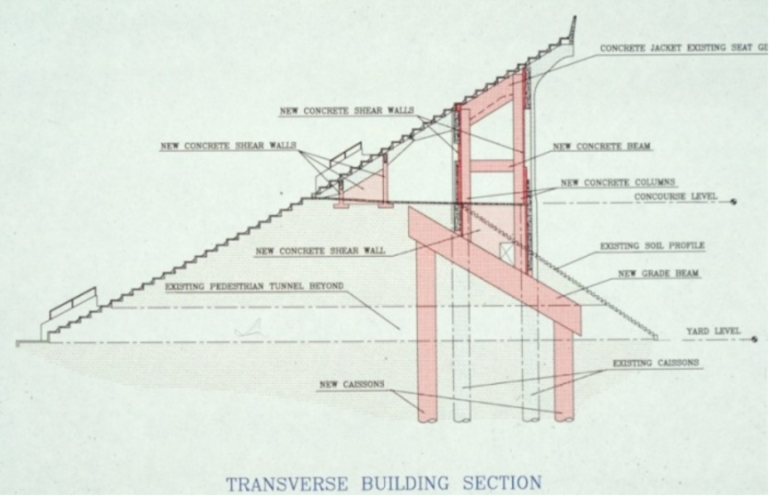


Figure 2 - Building in San Miguel in damaged state
(wall damage in basement on opposite side of building, left side of photo)

Los Angeles Memorial Coliseum

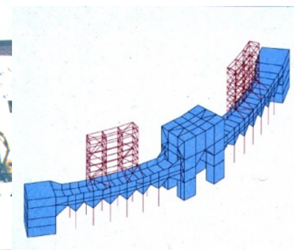
Los Angeles Memorial Coliseum

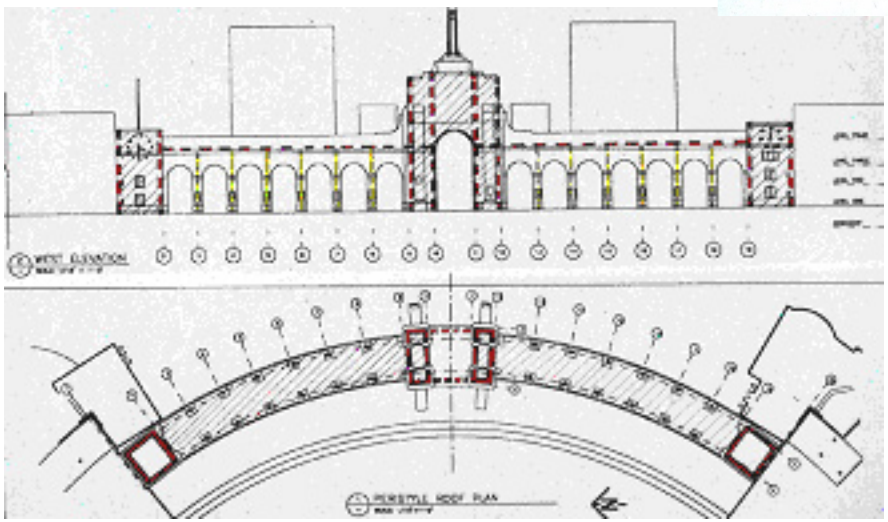


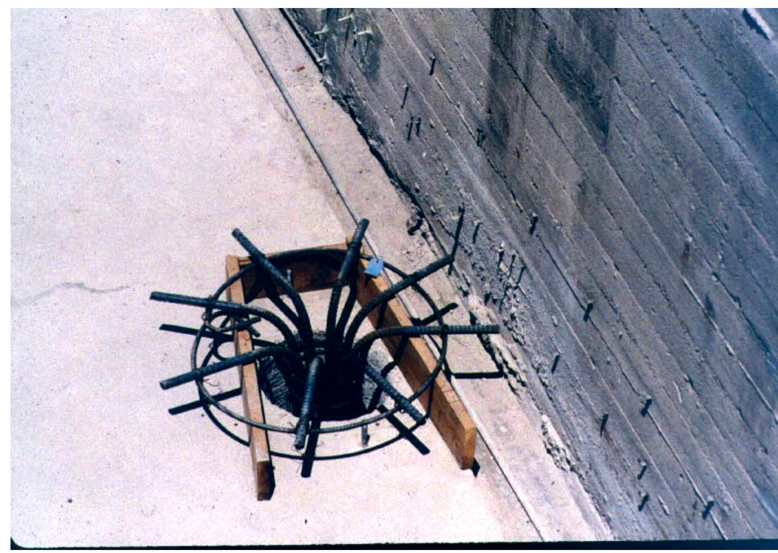
- New Frames + Foundation

Los Angeles Memorial Coliseum

- Peristyle Repair – Center Coring



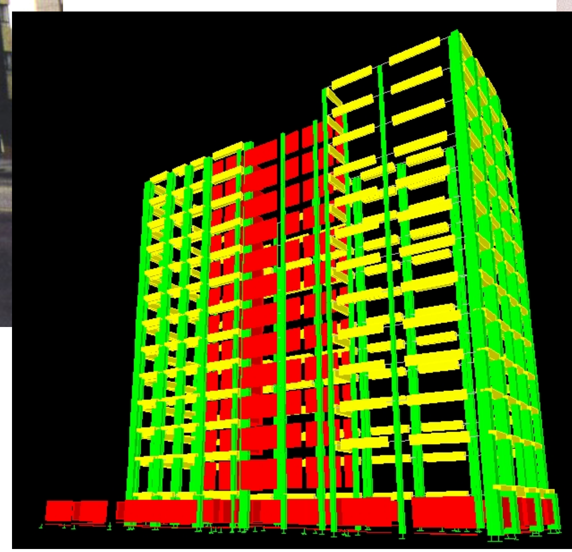




Jewish Federation

- 1953
- Suffered significant structural damage to concrete walls.
- New exterior concrete frame.

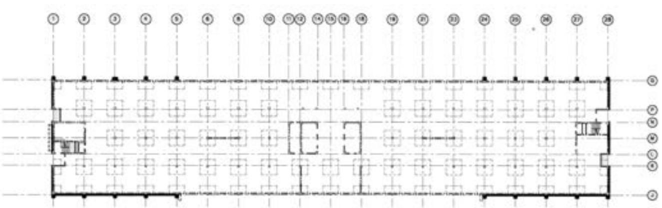
Before

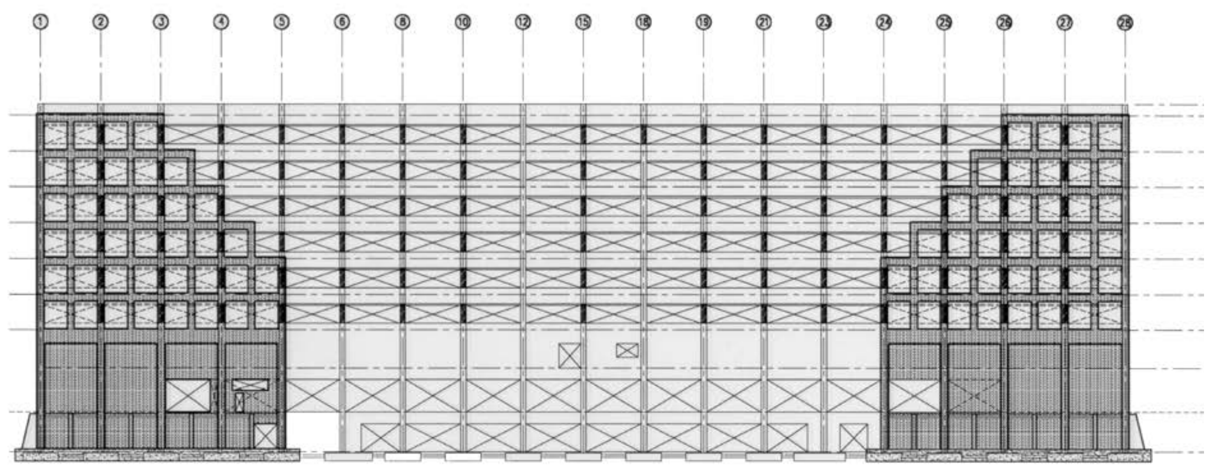


After

UCLA Harbor Medical Center

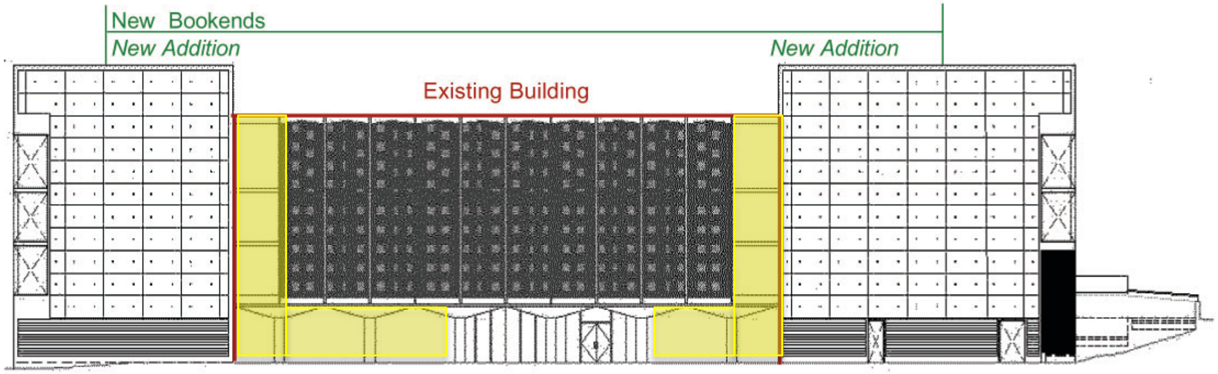
- 1946 Non-ductile concrete deep spandrel short columns.
- Deficient non-ductile shear walls.
- New exterior ductile concrete frames and shear walls along with composite fiber-wrapping of existing concrete piers.
- **reviewed under pending SB 1953 engineering criterion.**
- The hospital remained fully operational.



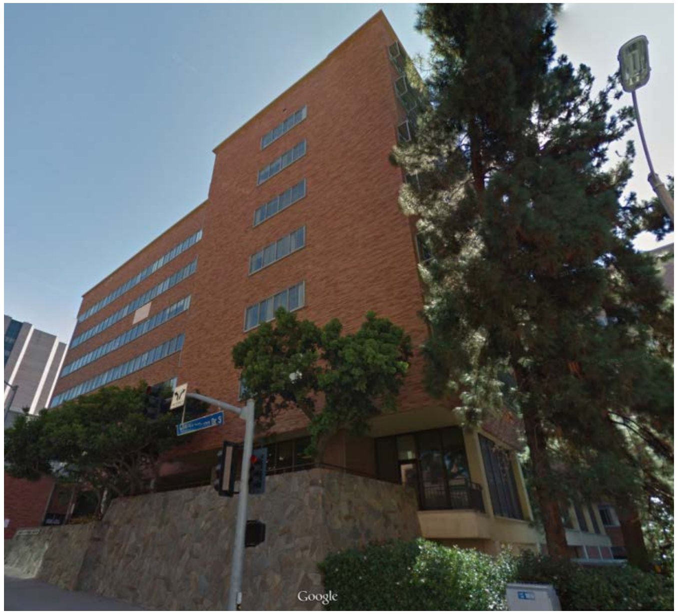


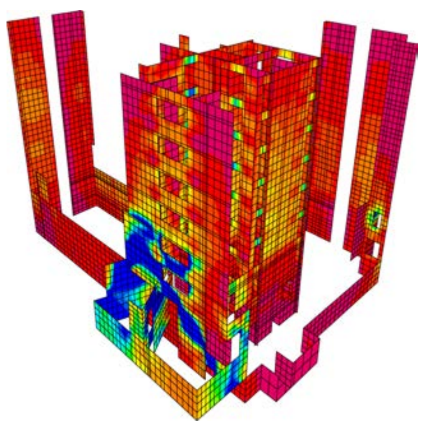
Whittier Library

- Discontinuous shear walls / frame over the ground floor circulation space that connects the campus.
- Strengthened with two new bookend structures.
- Additional space for expansion, preserving existing ground floor circulation.
- Allowed full occupancy during construction.



UCLA SOPH





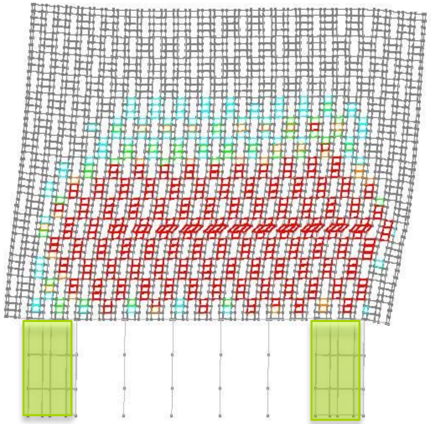
- 7 story (1965) Inadequate concrete shear strength
  - Discontinuous shear walls
  - Deep spandrel short column non-ductile frames.
- New “buttress” walls to address main wall discontinuous walls
- **Confirmed with nonlinear pushover to ensure adequacy of existing perimeter short columns**

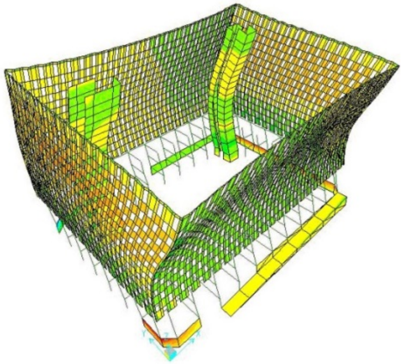
UCLA SOPH

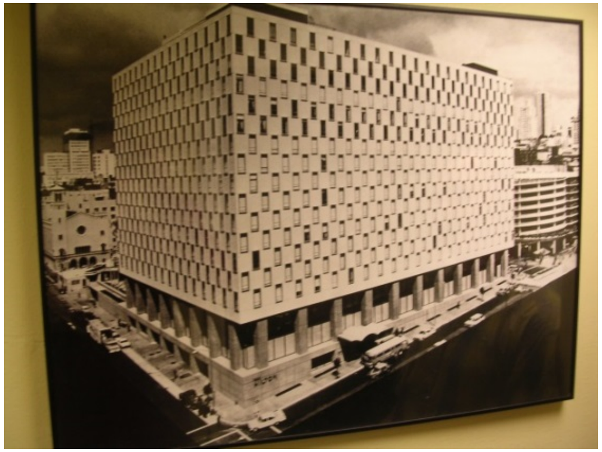
Photograph courtesy of Barton Phelps & Associates, Architects and Planners, Los Angeles. WWW.bpala.com. Photographer, Gregory Cheng.

San Francisco Hilton

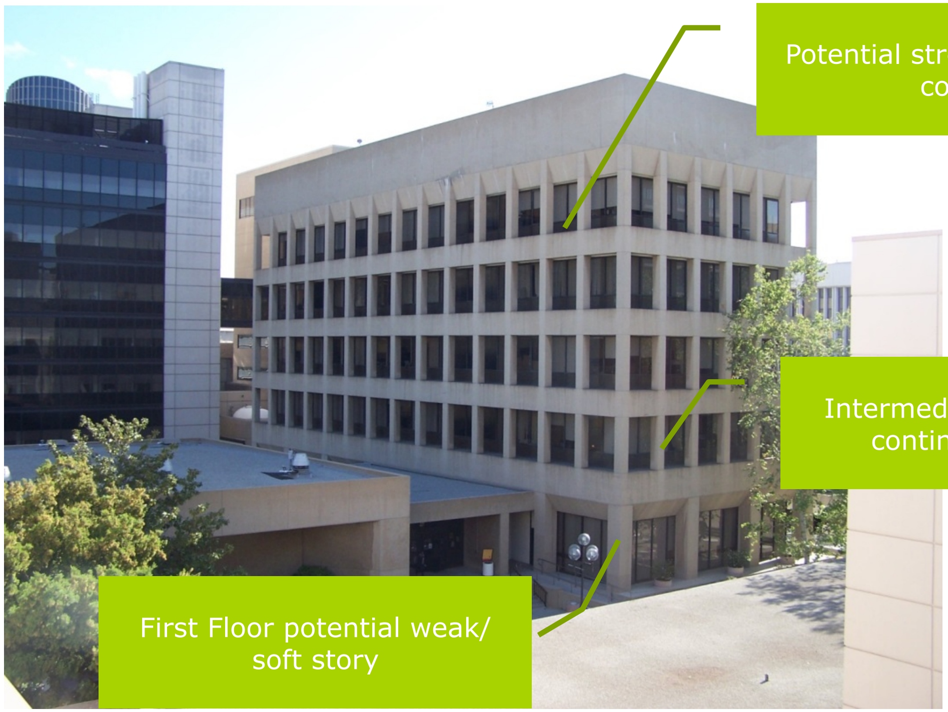
- 1964, 19-story with interior steel framing from 4th to 14th floor.
- Perimeter perforated light weight concrete walls above 4th floor.
- Two small interior concrete cores.
- Perimeter non-ductile concrete frames, lobby to 3rd floor.
- **"Brute Force" strengthening approach results in failure mechanisms developing in upper floors.**
- **Retrofit approach uses nonlinear analysis to "tune" strengthening of lower floors to utilize available strength of existing perforated walls in upper floors.**
- Added limited shear walls below 4th floor.



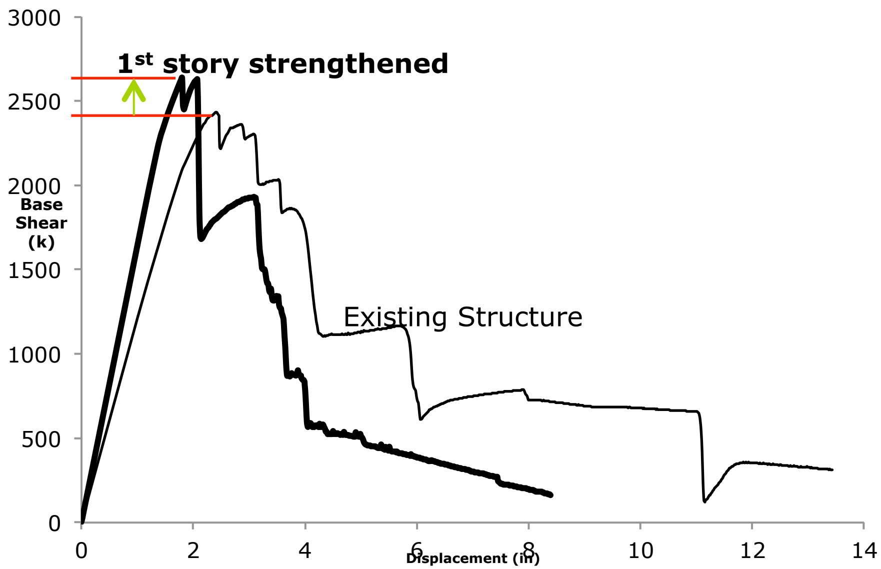


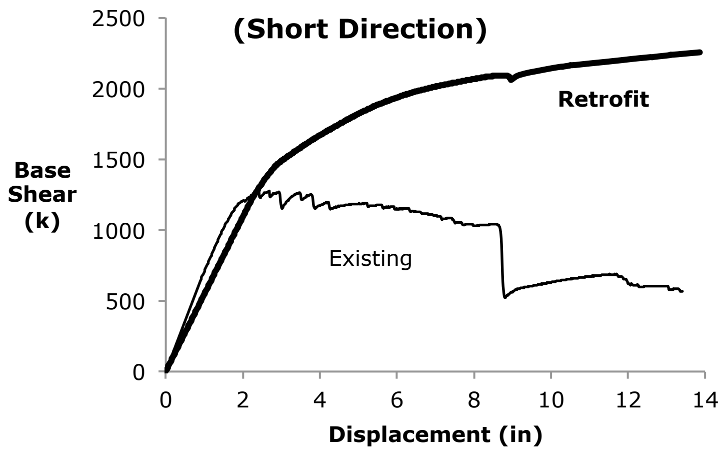


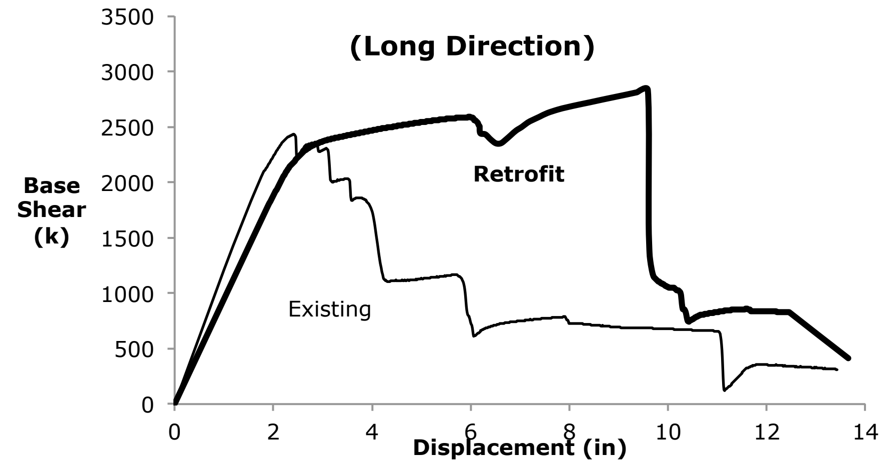
Original Building

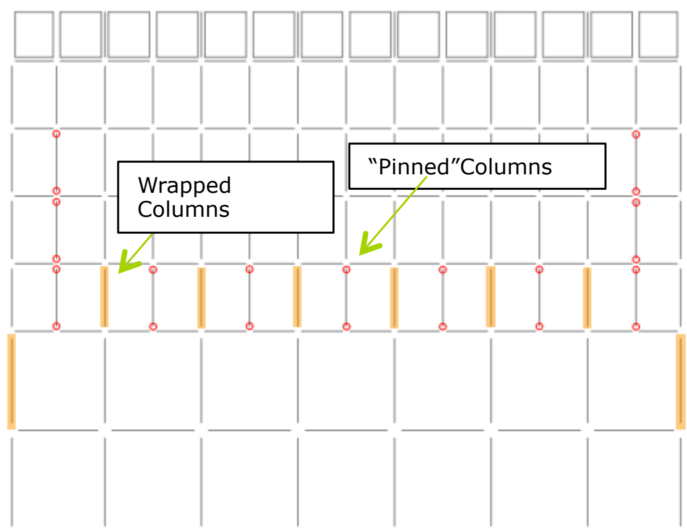


- 5 story (1968)
- Lack of adequate shear capacity in existing beams and columns
- Potential weak/soft 1st story
- 3D nonlinear time history response analysis
- "Brute" force strengthening approach results in failure mechanisms developing in upper floors





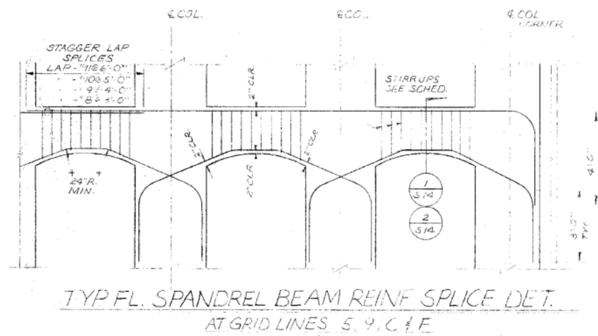


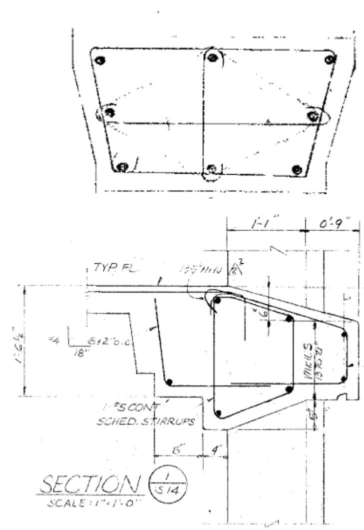


- Retrofit approach: Make building more flexural/ ductile
- FRP selected beams and columns on first 3 floors for shear strength to promote flexural yielding
- "Pin" select existing columns by coring vertical bars to promote more distributed yielding along height of structure

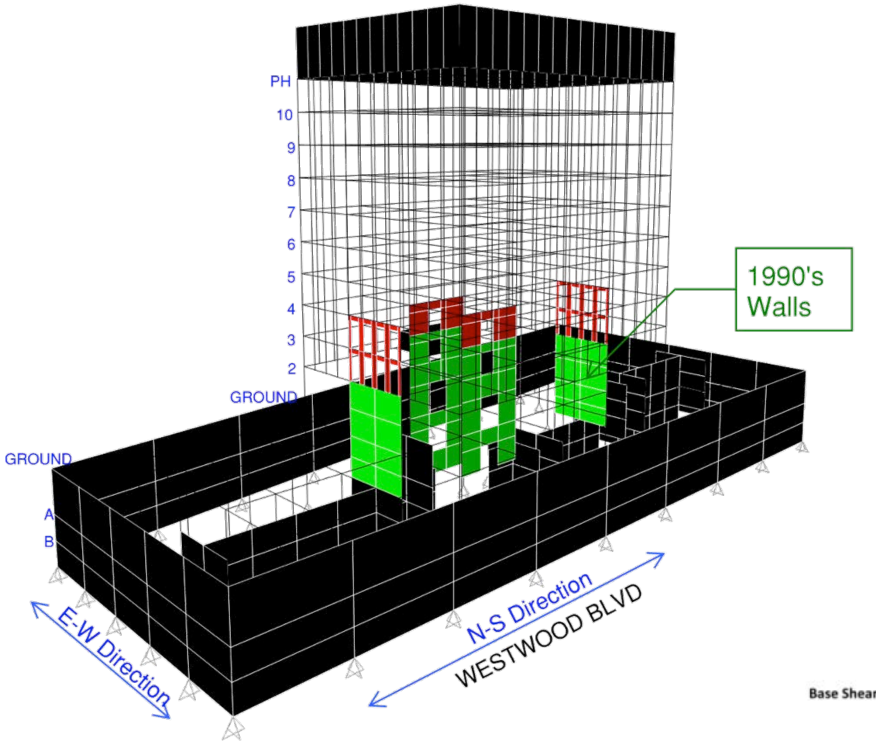
UCLA 924 Westwood

- 1970's 10 story tower – 3 below grade.
- Frame columns lack confinement in upper floors.
- Frame beams lack shear reinforcing.
- Lightweight concrete.
- 1990 retrofit to remove existing soft / weak story at base, however new walls did not extend to foundation.
- Linear analysis reports majority of existing moment frames are overstressed.

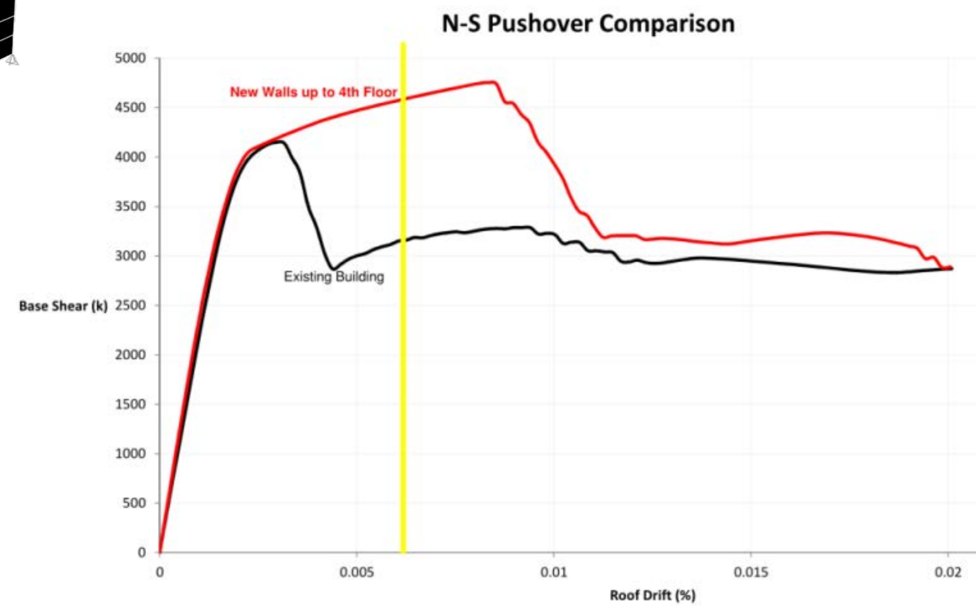




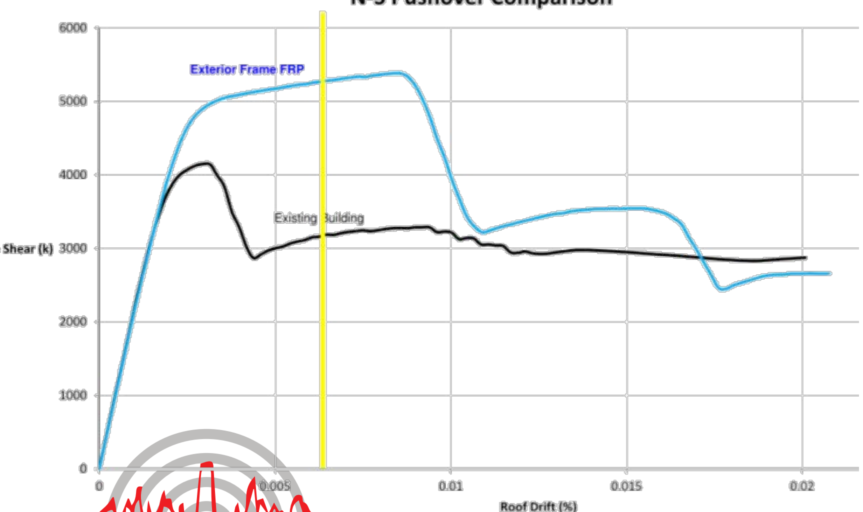
UCLA 924 Westwood

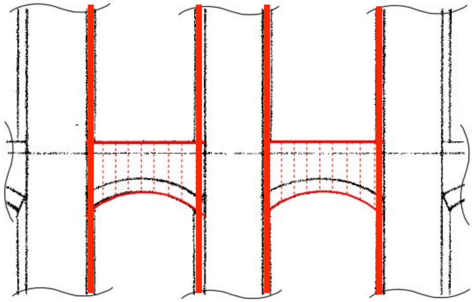


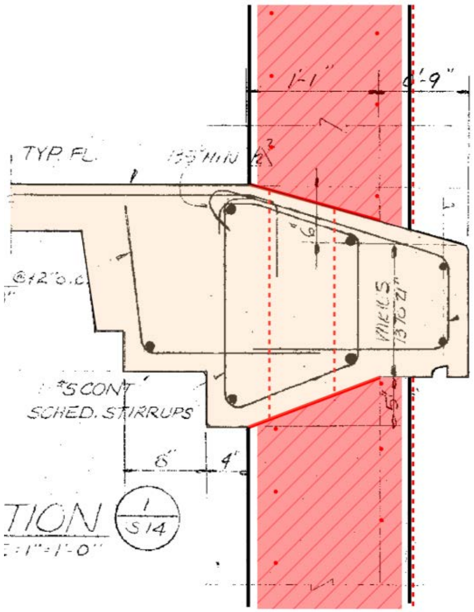
- Additional Walls
- "Pushes" demand up the tower frame



UCLA 924 Westwood

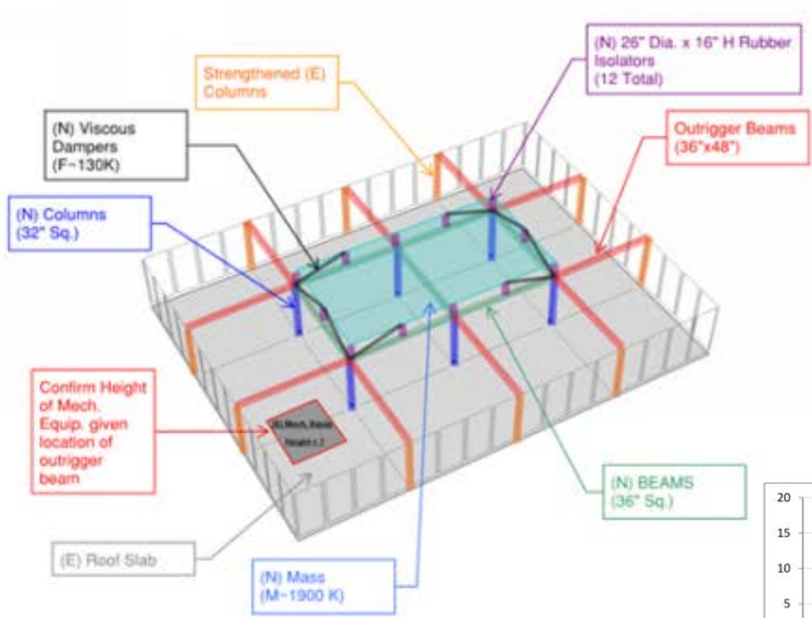




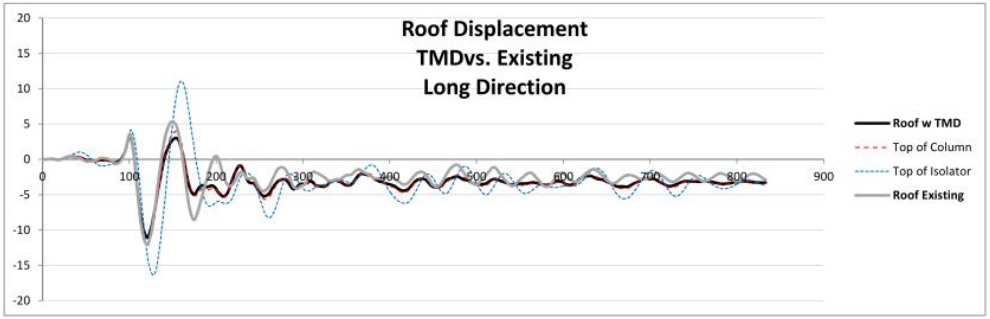


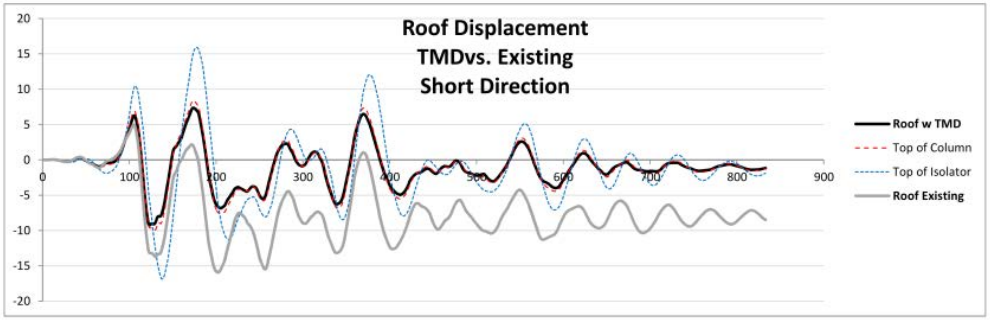
- Frame FRP Strengthening
- Aesthetics issues

UCLA 924 Westwood



Scheme 3





- Tuned Mass Damper at roof to counteract seismic movement.

UCLA 924 Westwood

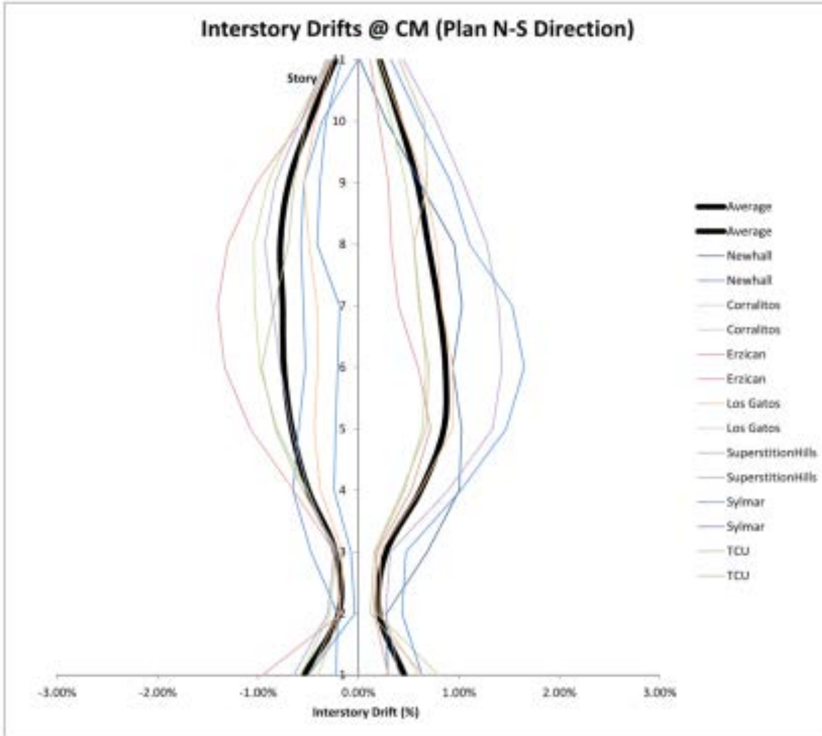


Figure 13 – BSE-2 Interstory Drifts

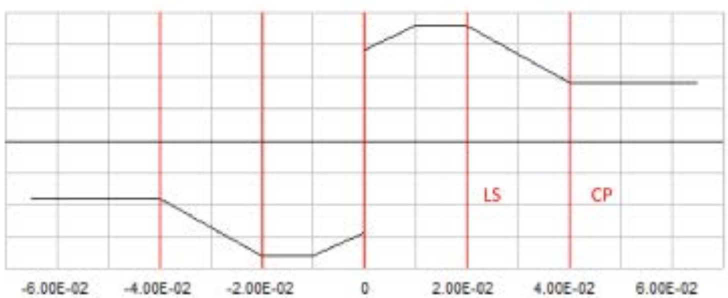
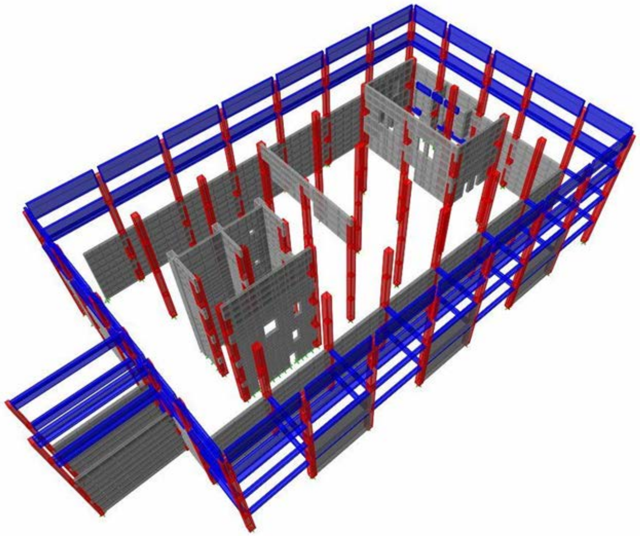


Figure 8 – Typical Moment Frame Beam Flexural Rotation Hinge

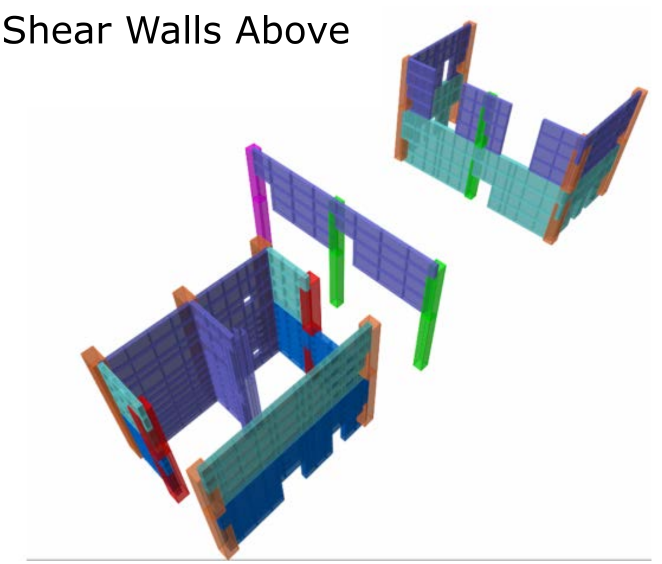
- Nonlinear Time History Analysis.
- In depth independent peer review adds confidence and reliability to the analysis.
- A good example of being able to take advantage of slightly better-than-typical detailing of the era (1970).
- Extra ductility and energy dissipation captured in the nonlinear analysis, not represented in the linear analysis.

Practice of the future mitigation by comprehensive analysis.

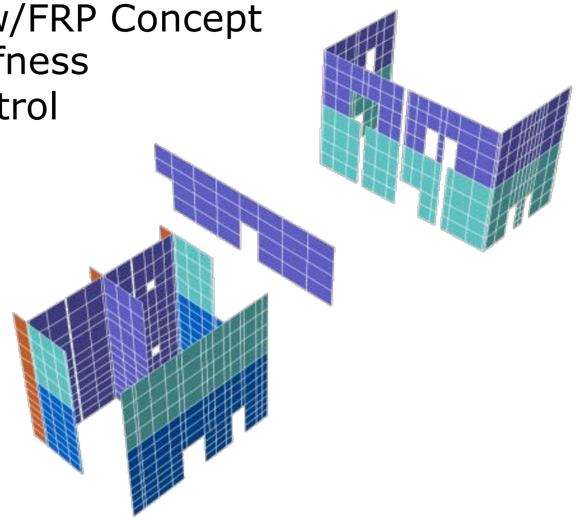


- 2 story above, 2 story below (1962)
- Discontinuous shear walls
- Thin walls with minimal reinforcing
- Shear dominated global behavior
- Nonductile exterior concrete frame

Existing Shear Walls Above Ground



Slotted Wall w/FRP Concept
– Reduce Stiffness
- Flexure Control



- Remove discontinuous walls above 2nd floor
- Slit walls to ensure flexural behavior
- FRP existing walls to enhance shear strength and boundary elements
- Philosophy:
  - Attract less seismic demand with better energy dissipation for remaining walls
  - Enhance existing walls rather than add new structure – difficult to compete with stiffness of existing walls

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