Structural Models used to Evaluate GMSM Methods

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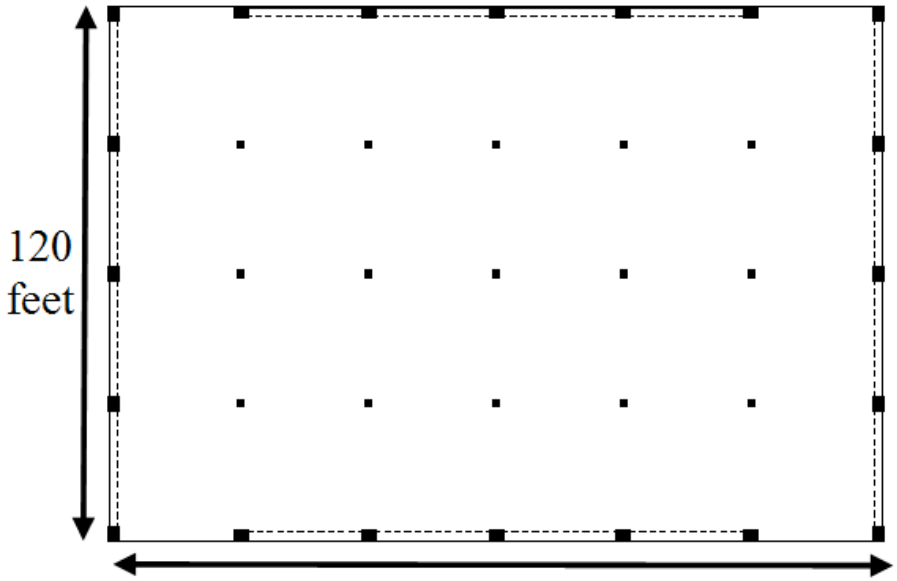
Purpose and Goal

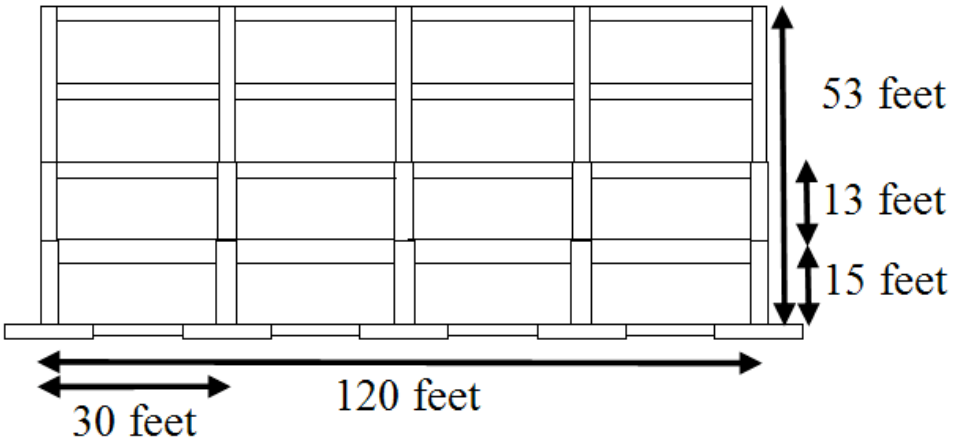
- Develop a representative set of structural models.
- Use these models to evaluate various GMSM methods, to determine which methods work best for which types of structures.

Building 1: 4-story RC SMF

- 4-story perimeter frame, 30’ bay widths, designed to have strength and stiffness distribution expected in practice
- Design Code: 2003 IBC
- Design base shear of 9% of weight

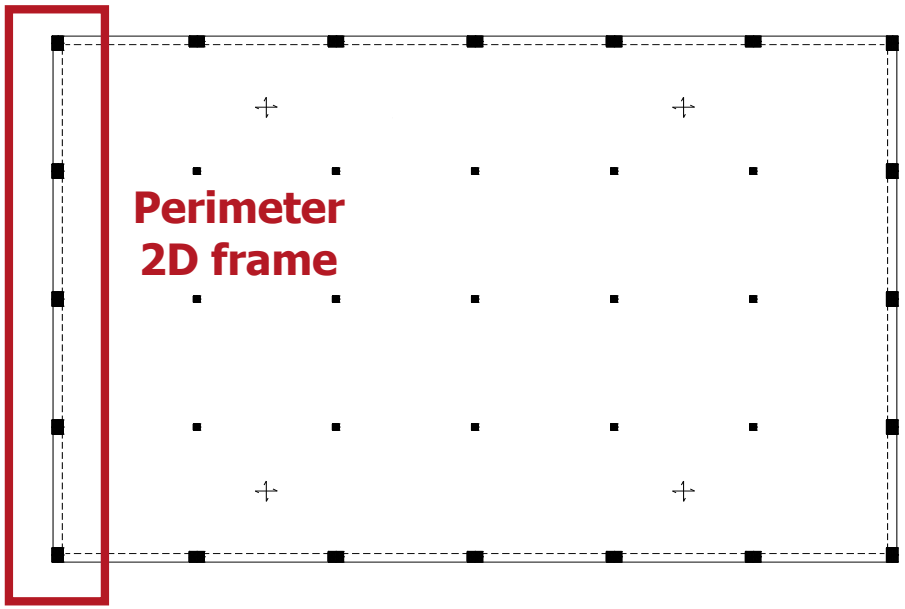


Plan View

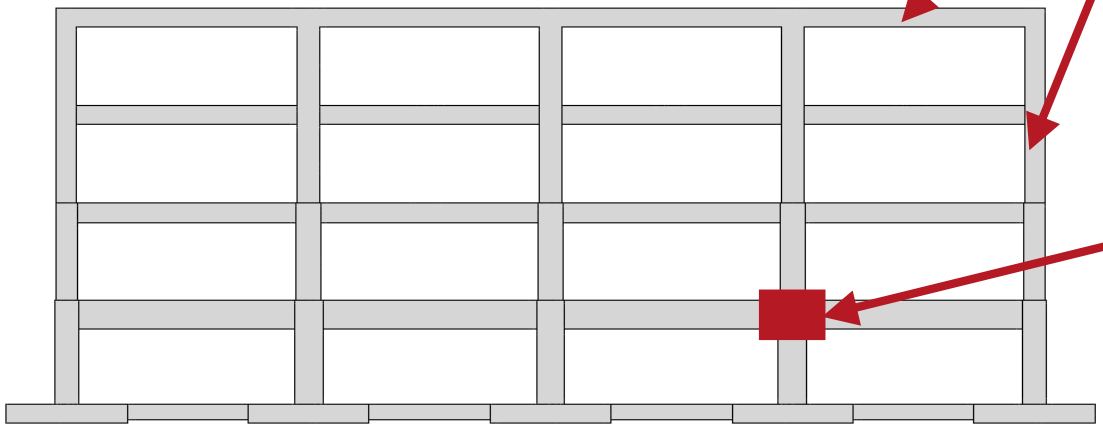


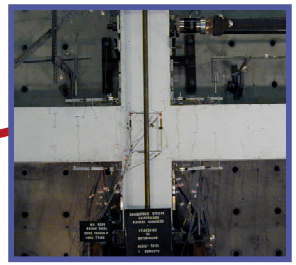
Elevation View

Building 1: Structural Modeling



Plastic Hinge Model





Joints with panel shear springs

Image: Paul Cordova of Stanford University

Building 1: Structural Modeling

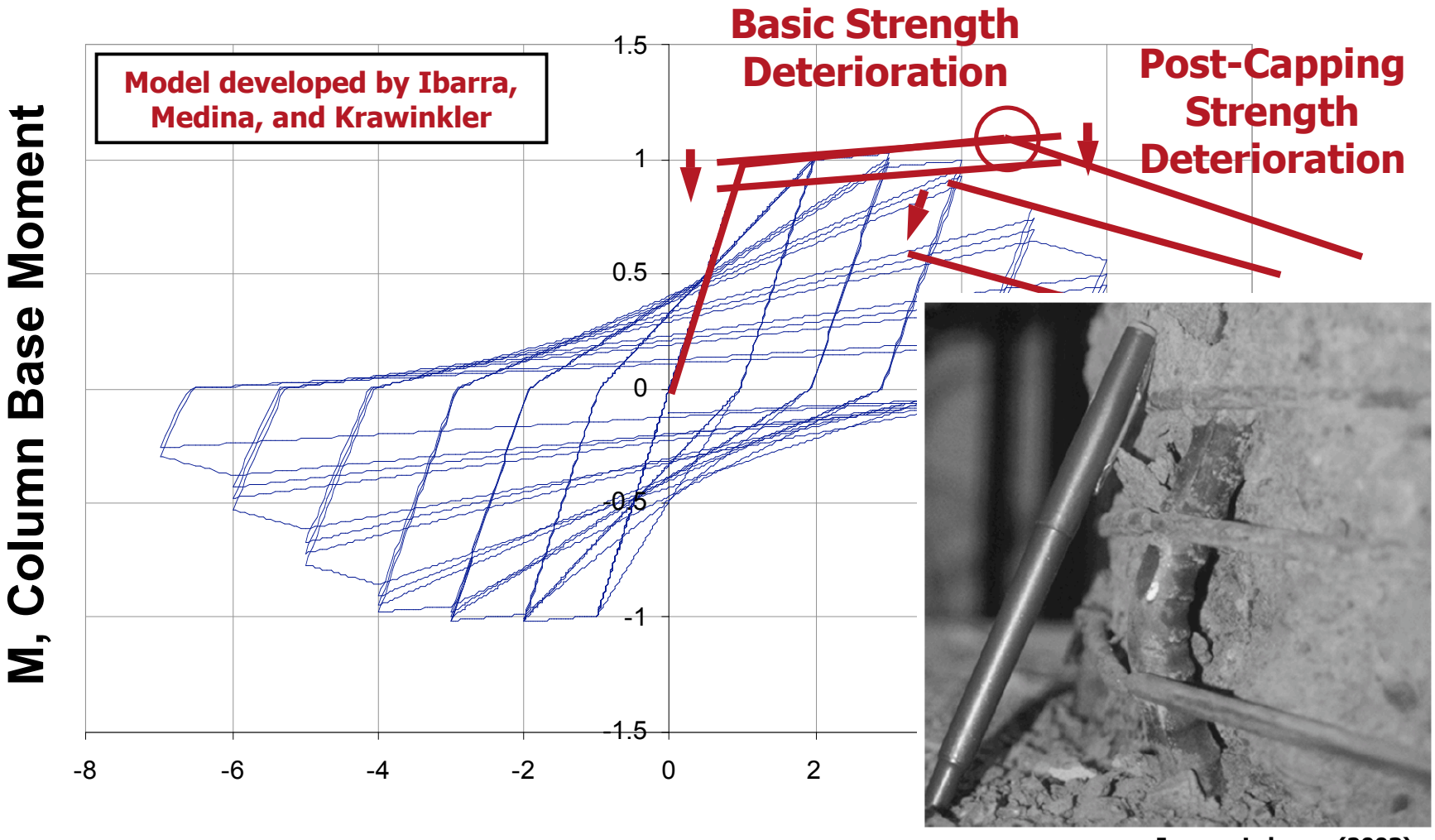


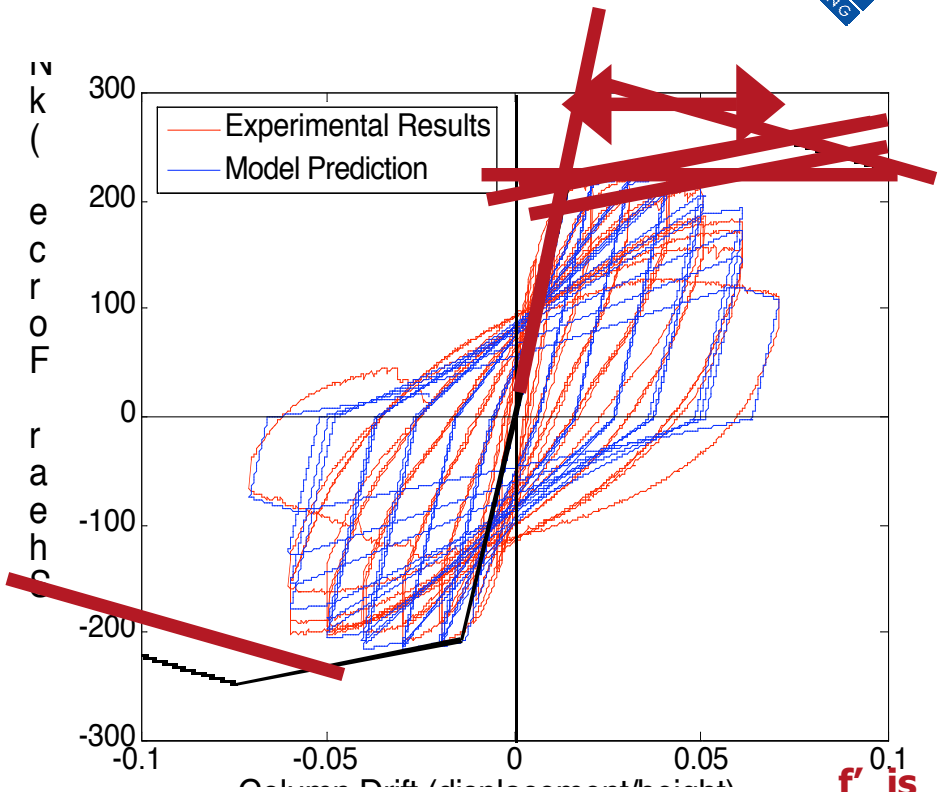
Image: Lehman (2003)

Building 1: Structural Modeling

Model calibrated to 255 flexurally dominated test from PEER Structural Performance Database (Berry and Eberhard)

Model Parameters to be Predicted:

- **Strength (easiest)**
- **Initial stiffness**
- **Post-yield stiffness**
- **Plastic rotation capacity**
- **Negative post-cap slope**
- **Cyclic deterioration rate**



a_{sl} – bond-slip – 0 or 1

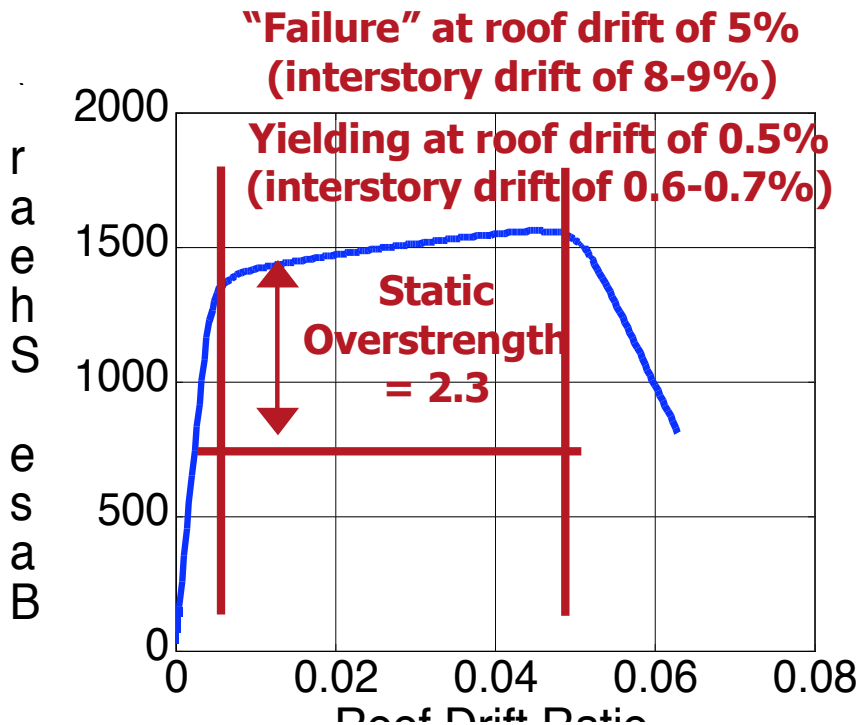
v is axial load ratio $[P/A_g f'_c]$

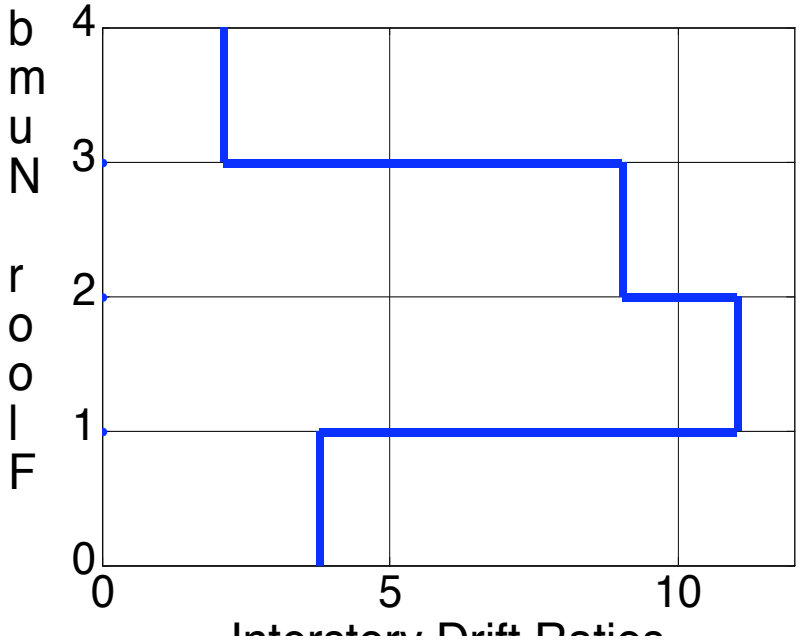
ρ_{sh} is the lateral confinement ratio

f'_c is concrete strength in MPa

Building 1: Period and Static Pushover

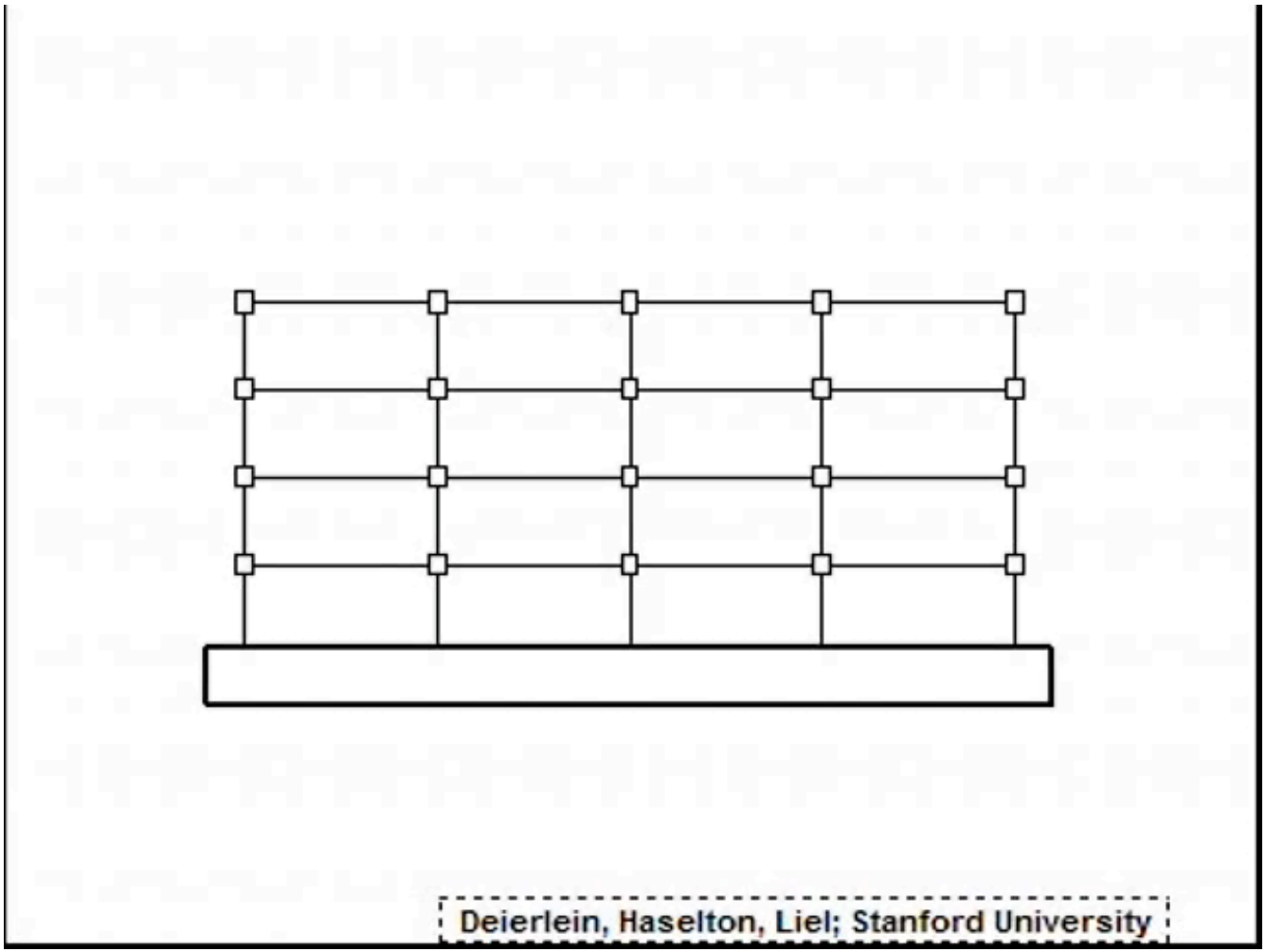
- $T_1 - T_3$ (sec) = 0.97, 0.35, 0.18
- Mass participation for modes 1-3: 0.81, 0.12, 0.06





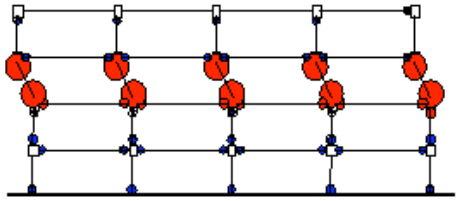
Building 1: Collapse Video

- Loma Prieta motion (Gilroy array #3 station) scaled to intensity that just causes structural collapse.

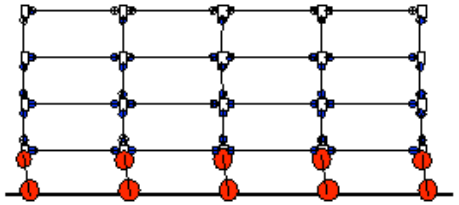


Building 1: Collapse Modes

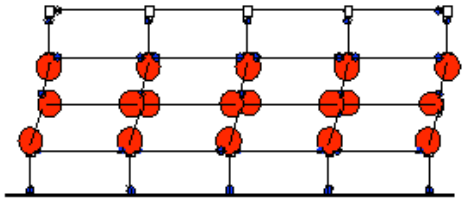
- Nonlinear dynamic failure modes



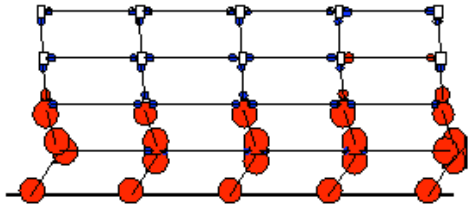
(a) 40% of collapses



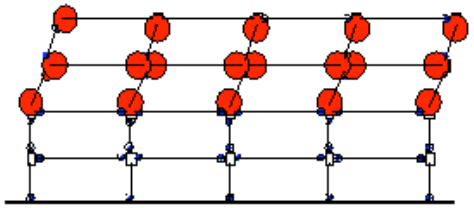
(b) 27% of collapses



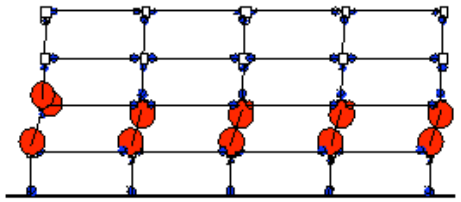
(c) 17% of collapses (PO)



(d) 12% of collapses



(e) 5% of collapses



(f) 2% of collapses

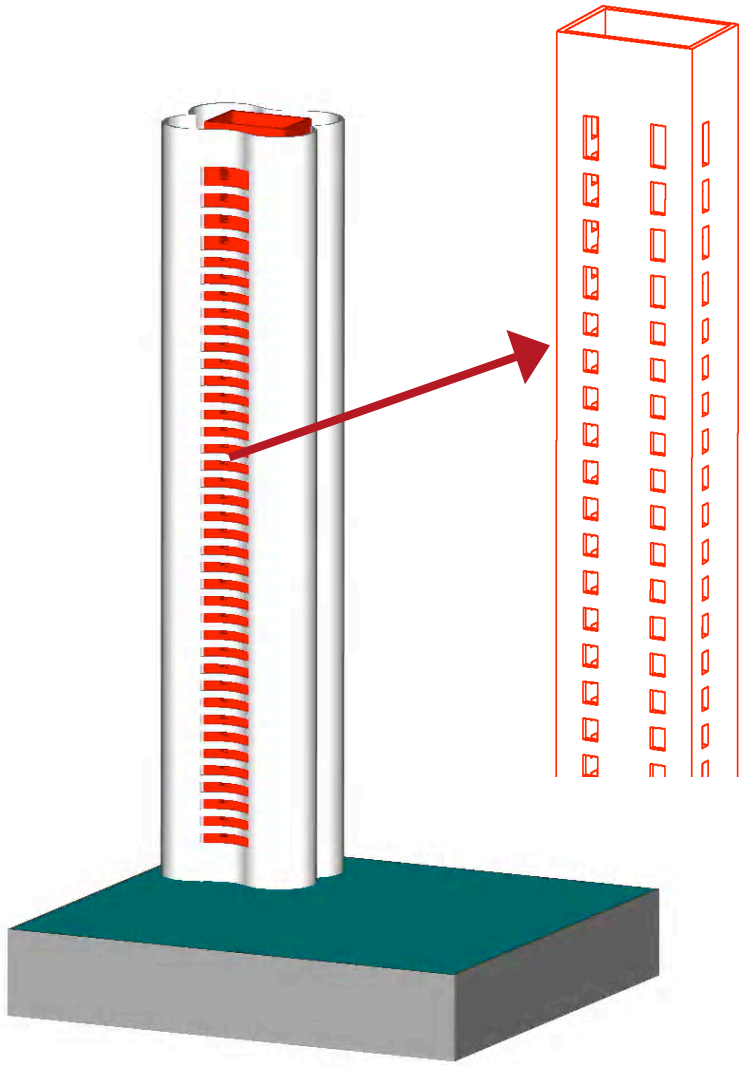
Summary of Buildings (16 total)

- RC Frames (Haselton, Liel, Dean, Deierlein, ATC-63):
  - Buildings:
    - 4-, 12-, 20-story ductile SMF (2003 design)
    - 12-story weak story SMF (2003 design)
    - 12-story non-ductile (1967 design)
  - Models: 2D frames modeled using OpenSees (consistent with 4-story RC SMF)
- Steel Frame Instrumented Buildings (Kalkan, CSMIP):
  - 6- and 13-story (1975 era)
    - 2D frames modeled using OpenSees - fiber elements
  - 19-story (1967 era)
    - Building includes moment frames and X-braced steel frames, layout indicates possible torsion
    - 3D frame modeled using OpenSees - fiber elements and truss elements for braces

Summary of Buildings (16 total)

- Generic Frames and RC Walls (Zareian):
  - Two 12-story ductile frames (fundamental periods of 1.2s and 2.4s)
  - 12-story ductile planar RC walls (fundamental periods of 0.6s and 1.2s)
  - 2D frames/walls modeled using Drain (similarly to 4-story RC SMF)
- RC Shear Walls (Haselton, Takagi, ATC-63)
  - 12-story special core wall (2003 design)
  - 2D wall modeled using OpenSees
- Tall Building Initiative (Yang, McQuiod, Moehle, Tall Building Initiative)
  - 28 and 34 story RC frames (2D frames modeled using OpenSees – fiber elements)
  - 48 story core shear wall (3D wall modeled using Perform3D – details to follow)

Tall Buildings - 48 story shear wall

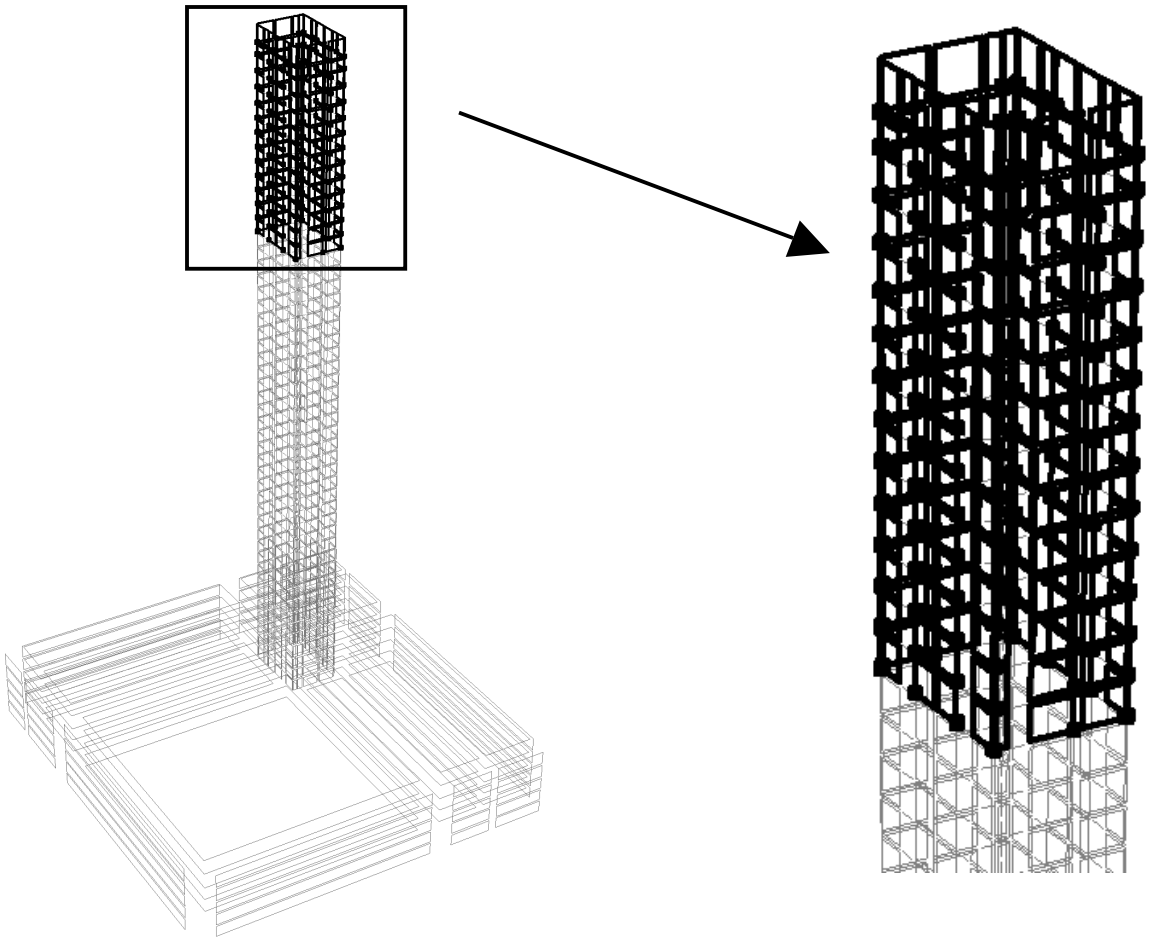


- 48 story shear wall building (43 stories and 420’ above ground)
- Actual building under construction
- Dimensions changed to protect identity of building

[Slide content from Yang/McQuoid/Moehle]

48 Story Wall – Perform3D Model

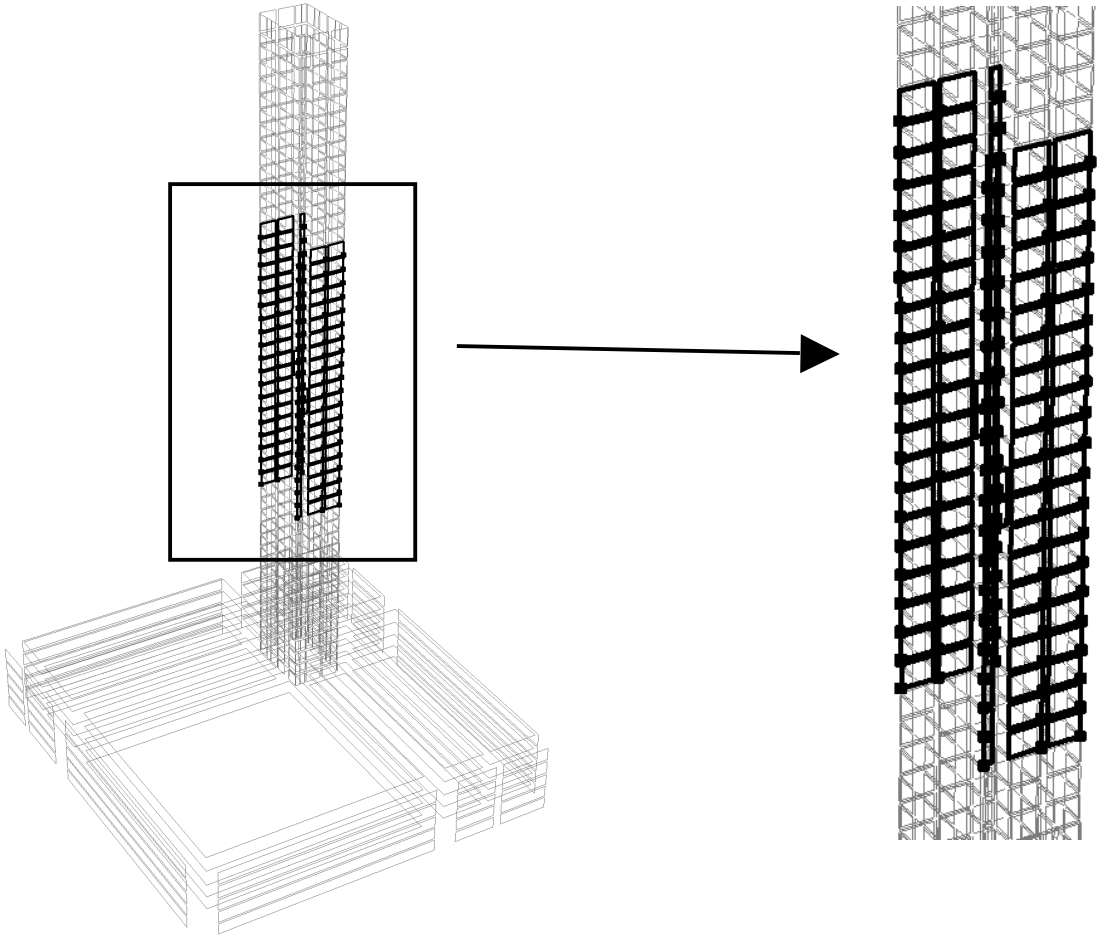
Elastic shear wall elements



[Slide content from Yang/McQuoid/Moehle]

48 Story Wall – Perform3D Model

Elastic shear wall elements



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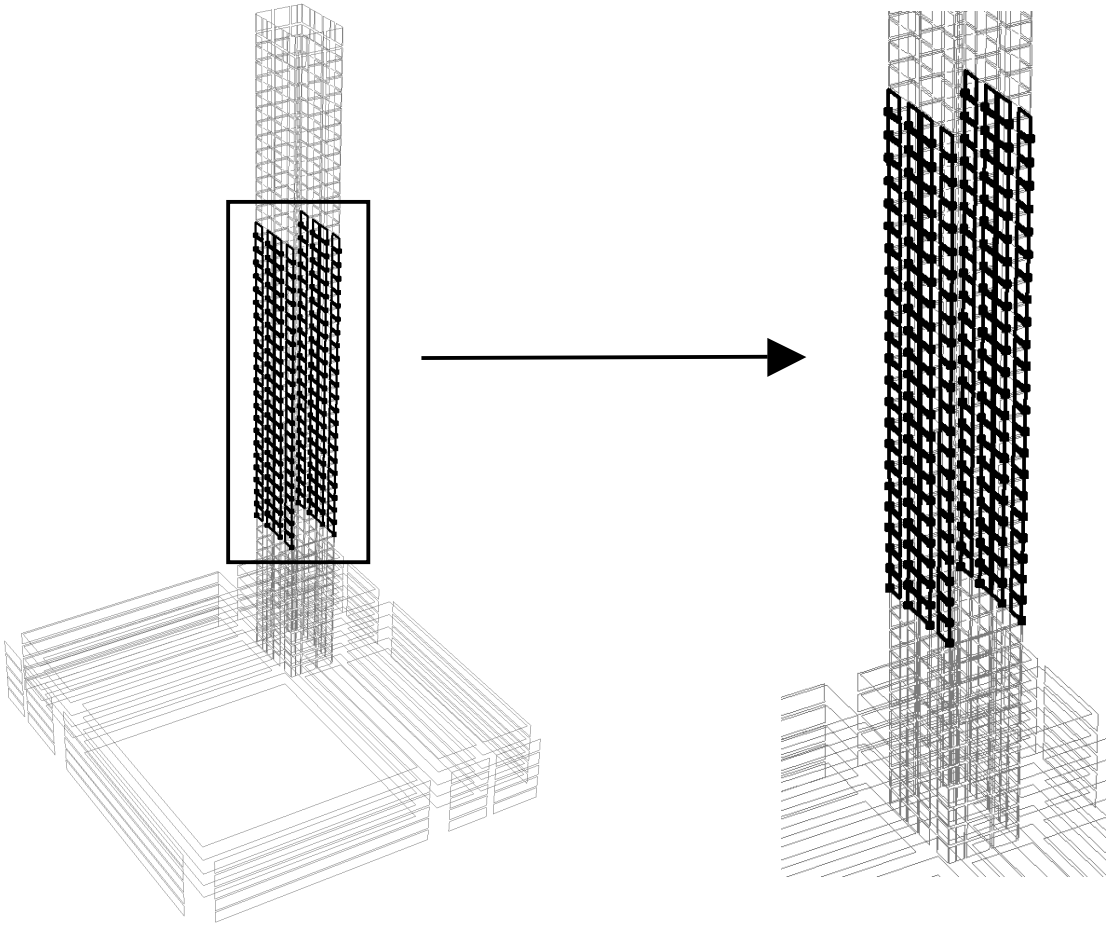
48 Story Wall – Perform3D Model

Elastic shear wall elements



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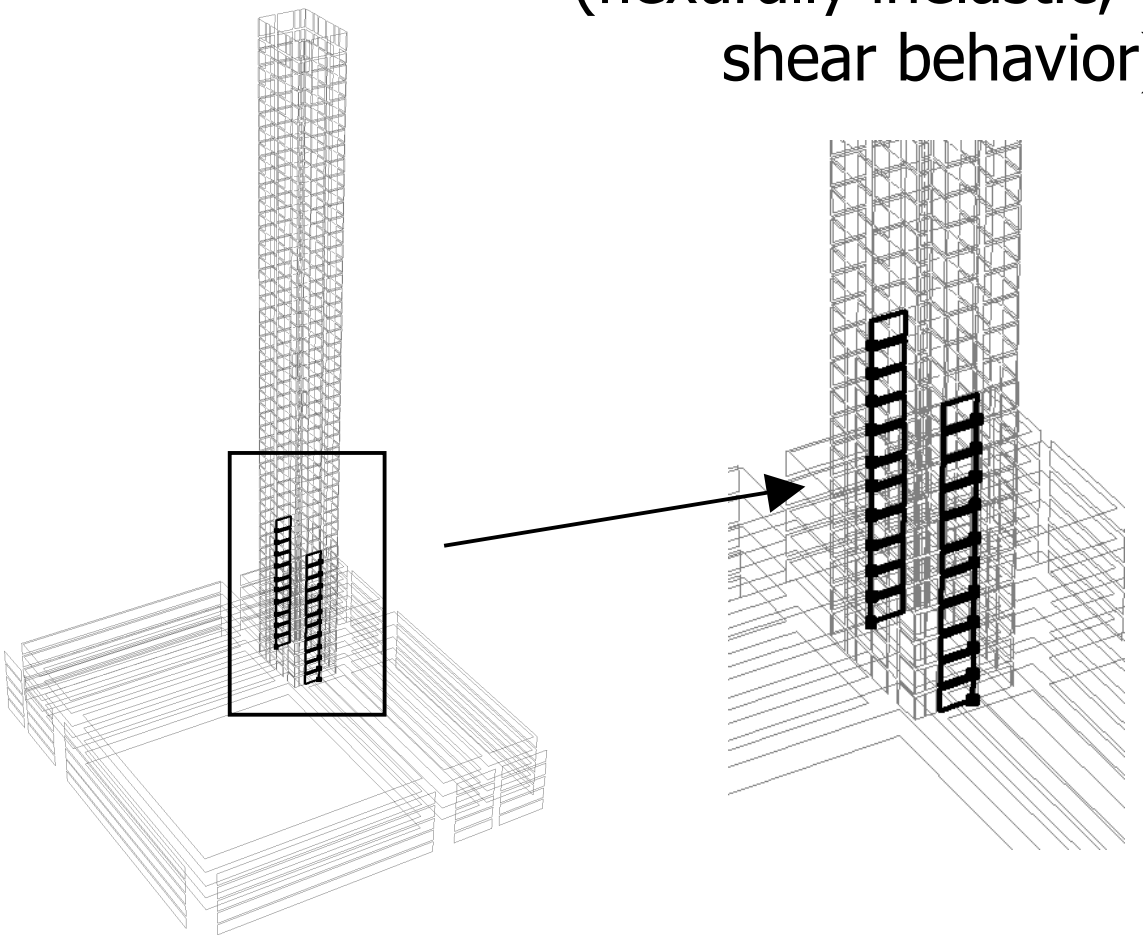
48 Story Wall – Perform3D Model

Inelastic shear wall elements (flexurally inelastic, elastic shear behavior)



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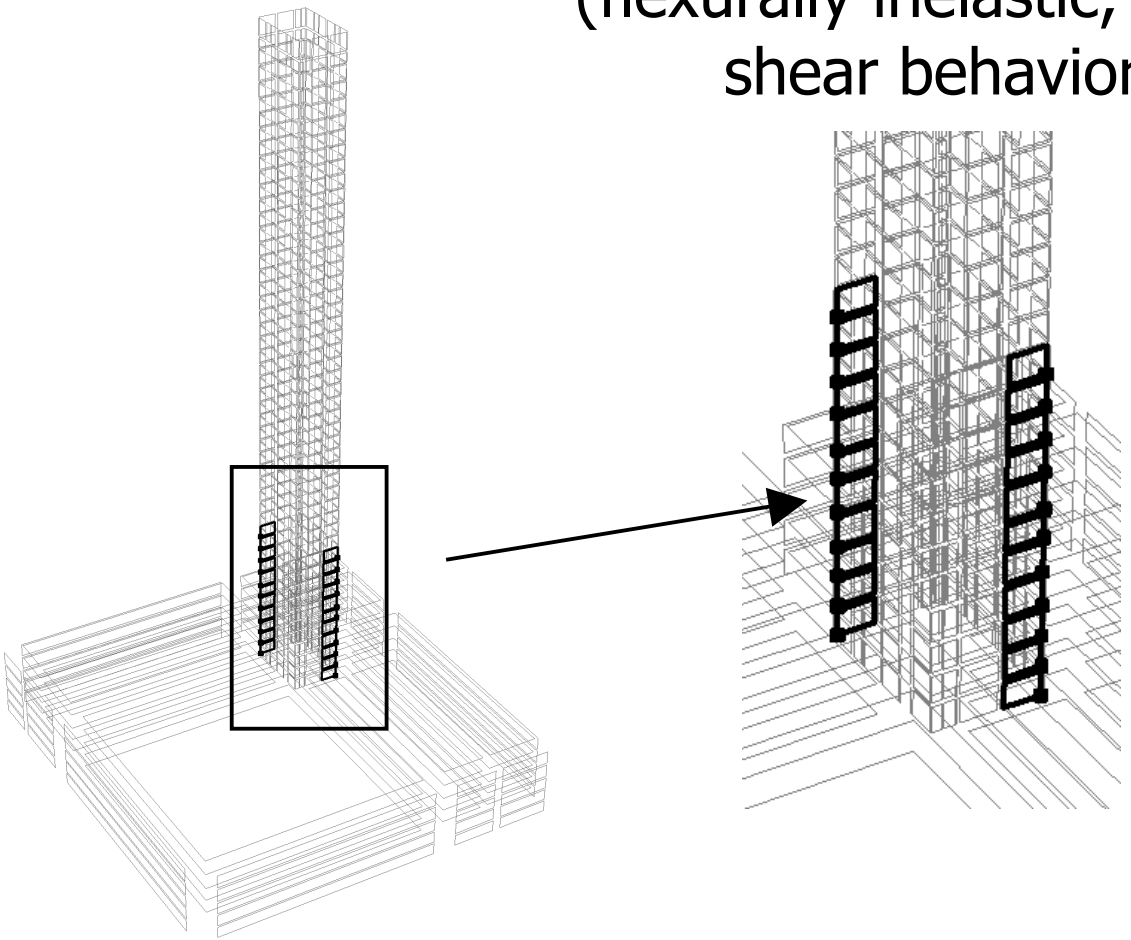

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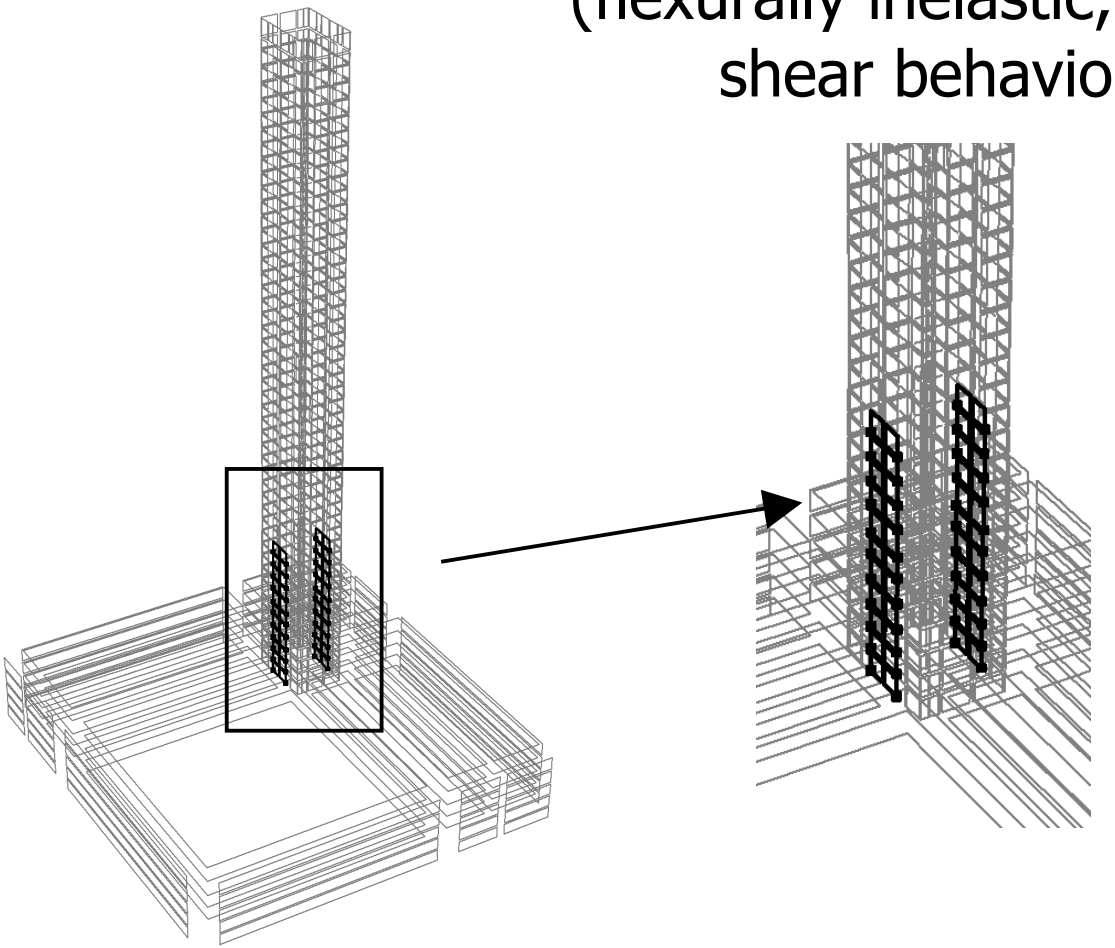

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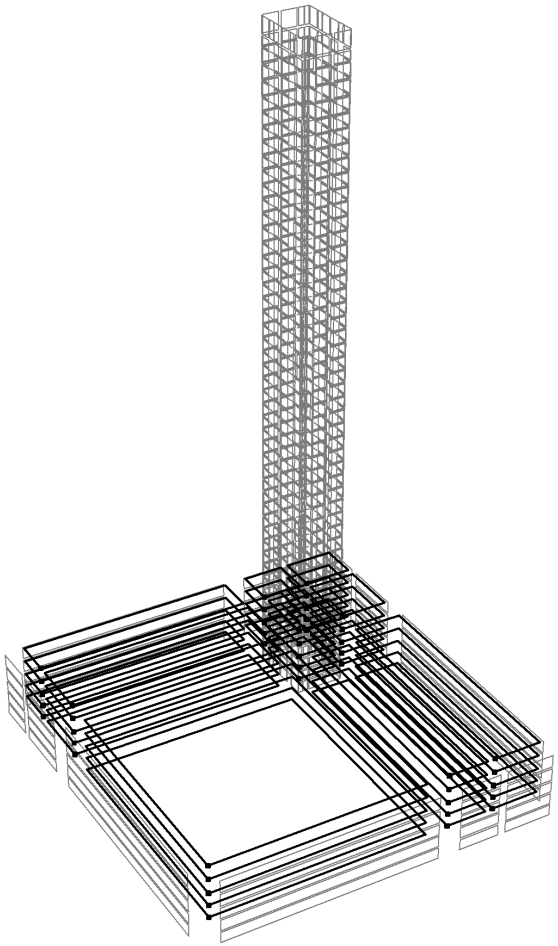
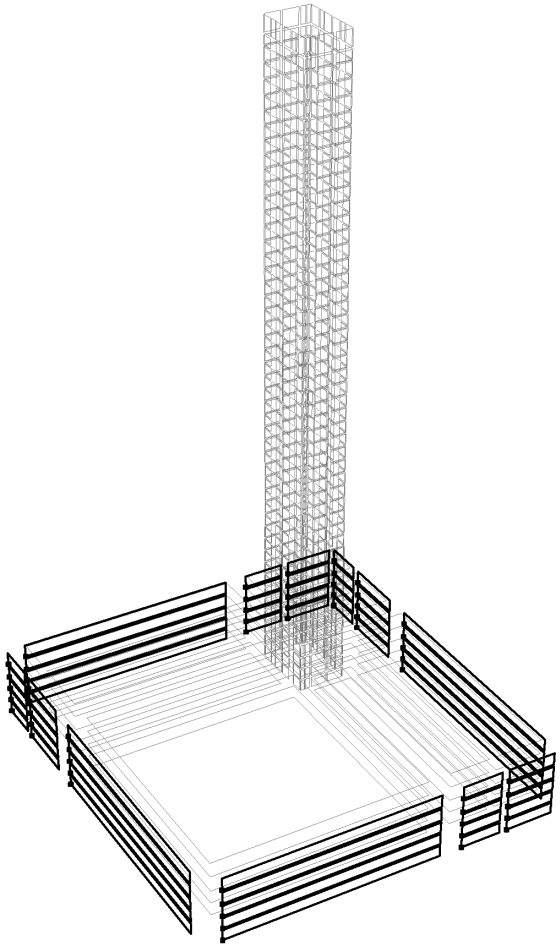
48 Story Wall – Perform3D Model



- Parking garage slab diaphragms (10”, 12”)
- Modeled with elastic shell elements (bending and membrane action)

[Slide content from Yang/McQuoid/Moehle]

48 Story Wall – Perform3D Model



- Basement walls (10”-22” thick)
- Modeled with elastic shear wall elements

[Slide content from Yang/McQuoid/Moehle]

Closing

- Thank you for your attention.
- I would appreciate any questions or suggestions.