Nonlinear Dynamic Seismic Evaluation of a Pre-Code Concrete Shear Wall Tower

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Building Description

- Pre-code reinforced concrete shear wall building.
- 17 above ground levels, and a partially exposed basement.
- Located on west coast in area of high seismic hazard.
- Height = 164 ft.
- 6” concrete flat slabs
- 6” to 12” thick walls
- 8’-6” typical floor to floor height

Fig 1. Overall view of building analysis model.
Building Description (cont.)

- Figure shows wall layout for typical floor.
- Only 4 long walls in the center designed for seismic load.
- Many redundant walls, but no ductile detailing – “confinement steel” consists of #3 hoops around entire BZ @ 18”.
- Nominal f’c = 3-4 ksi.

Fig 2. Cut-away view of typical (2nd to 17th floor) concrete wall layout on typical floor plate. Designed shear walls indicated as SW1-SW4. Walls in green are 8” thick; purple are 7” thick; light blue are 10” thick; and dark blue are 6” thick.
Analytical Model

- LS-DYNA explicit solver
- Walls and Lower Floors:
  - Composite shell elements
  - Concrete – MAT_CONCRETE_EC2 (MAT_172)
  - Steel – MAT_HYSTERETIC_REINFORCEMENT (MAT_203)
- Spandrel Beams:
  - Elastic beams with cracked stiffness modifiers
- Upper Floors:
  - Elastic shells with cracked stiffness modifiers
- Fixed base model
- 2.5% damping

Fig 3. Overall view of building analysis model, with element and material types indicated.
Ground Motions

- 7 ground motions linearly scaled to match “MCE” spectrum conditioned to 1.0s.

*Fig 4. 2475-yr (MCE) event and UHS spectra (by Nicole Paul)*
1.0x MCE Simulation

- Peak (high-tide) tensile strain perpendicular to first crack shown.
  - Deformations x10
  - Yellow: Yield ($\varepsilon > 0.17\%$)
  - Red and Magenta: Rupture ($\varepsilon > 2\%$)

Fig 5. Response history video of building under MCE Subduction GM4
1.0x MCE Simulation (cont.)

Fig 6. Screenshot of building under MCE Subduction GM4

Fig 7. Screenshot of building
2.0x MCE Near Collapse Simulation

- Peak base shear stress:
  - Demand = $2.3 \sqrt{f_c}$
  - Capacity $\approx 4 \sqrt{f_c}$

- Apparent period:
  - Before 20s: $\sim 1.7s$
  - 20s to 30s: $\sim 3s$
  - End: $\sim 3.9s$

Fig 8. Near collapse run E-W base shear time history (2x MCE, Subduction GM4).
Shear taken at section just above the ground floor.
2.0x MCE Near Collapse Simulation (cont.)

Fig 9. Peak equivalent uniaxial compressive strain for near collapse run (2x MCE, Subduction GM4)

Fig 10. Time history of vertical stress near base in SW4 and adjacent walls (2x MCE, Subduction GM4)
2.5x MCE Collapse Simulation

- In right two windows, peak (high-tide) uniaxial compression strain plotted.
  - Deformation x1
  - Yellow: Softening ($\varepsilon > 0.22\%$)
  - Red: Crushing Onset ($\varepsilon > 0.43\%$)
  - Magenta: Spalled (zero stress)
- Prior to collapse initiation cycle, peak roof drift = 2.8%

Fig 11. Response history video of building under 2.5x MCE Subduction GM4
Thank you