Design and Modeling Issues Related to Diaphragms of Tall Buildings

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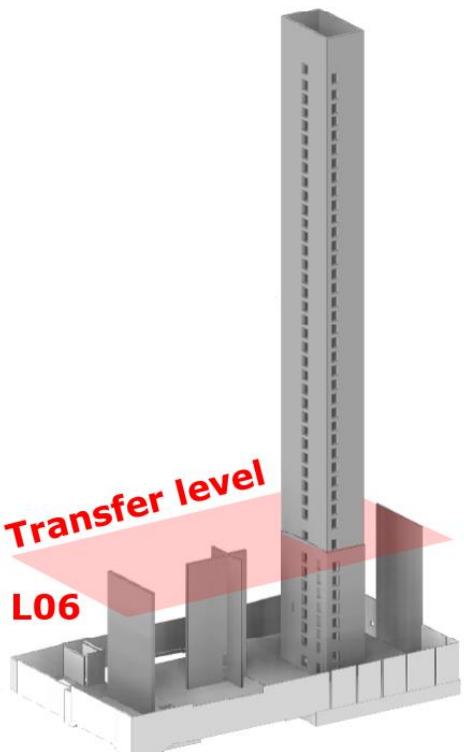
Introduction

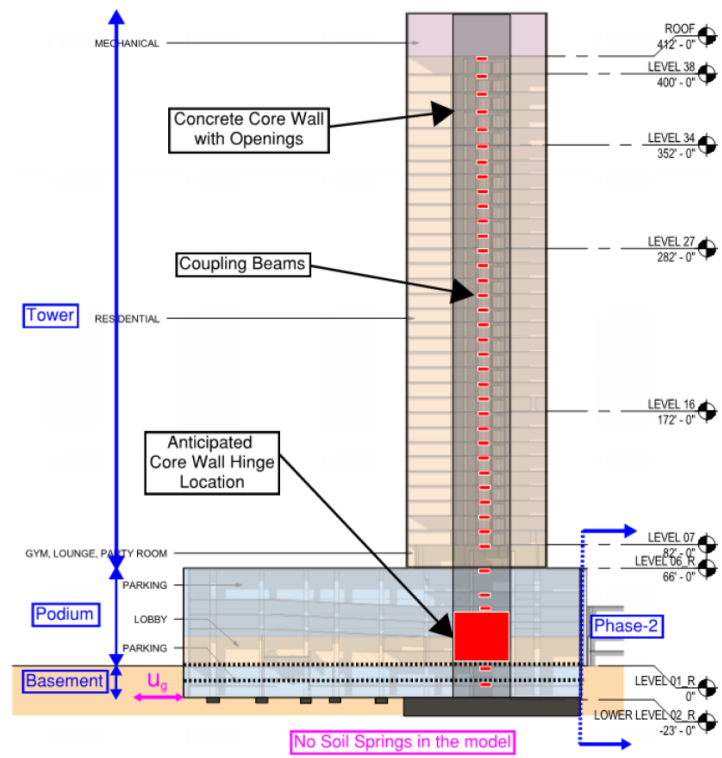
- Transfer Level Diaphragms experience large demands and complex behavior
- Need for comprehensive approach to analyze demands and design diaphragm components in Performance Based Design
- Various modeling and design approaches used in engineering practice

- **Objectives**
  - Investigate sensitivity to modeling configuration (Elastic vs. Inelastic) and effective shear stiffness
  - Guidance on use of simplified analysis models to determine demands

Building Description

- 38 – Story Residential building w/ 7 story podium
- Concrete corewall used for main Lateral Force Resisting System (LRFS)
- Designed using Performance Based Design Methodology per LATBSDC Guidelines

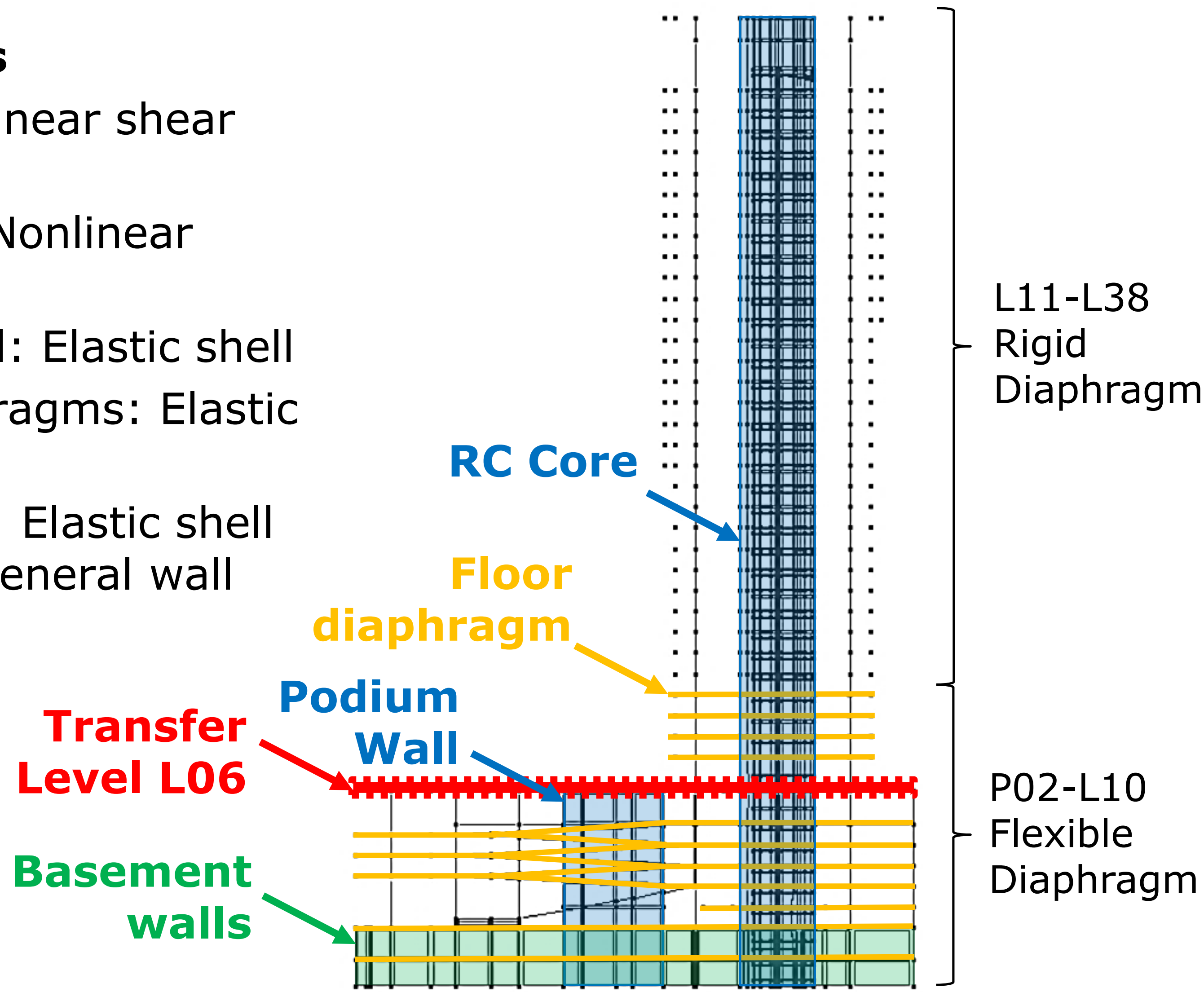




Perform 3D Model

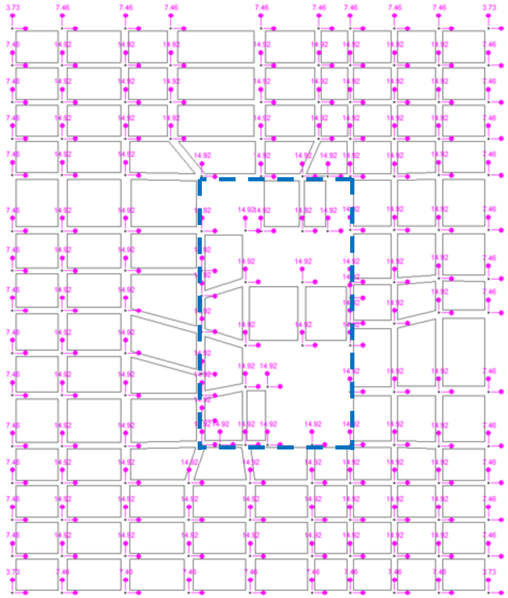
Model Elements

- RC core: Nonlinear shear wall
- Podium wall: Nonlinear shear wall
- Basement wall: Elastic shell
- Flexible diaphragms: Elastic shell
- Transfer level: Elastic shell or Nonlinear general wall

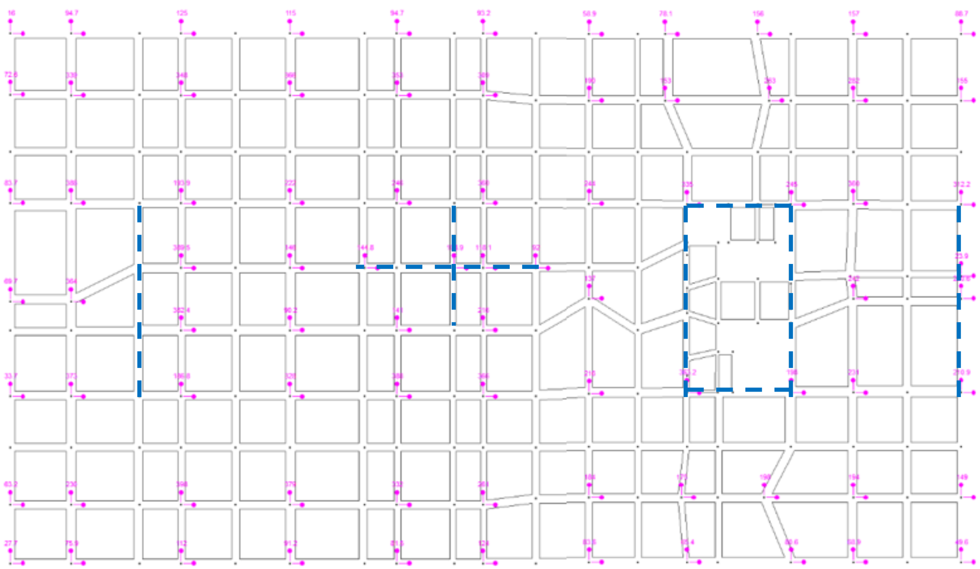


Typical Tower Level and Transfer Level

- Tower Level
  - Flexible Diaphragm
  - Fine Mesh with distributed mass
- Transfer Level
  - Semi-Rigid
  - Fine Mesh



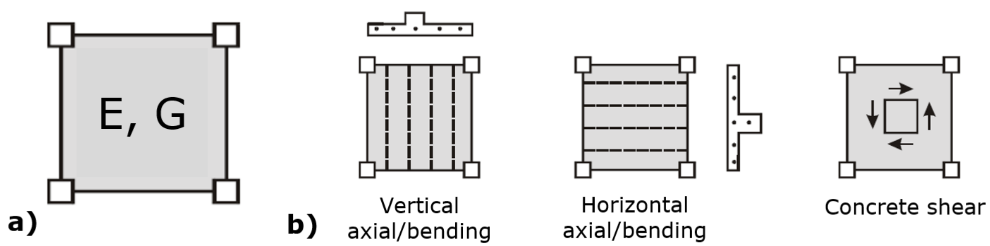
Tower Level



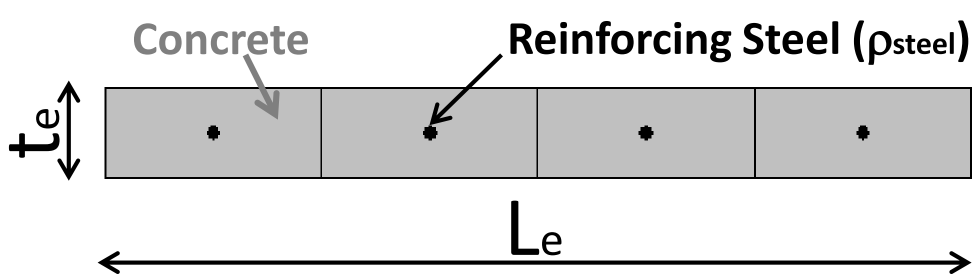
Transfer Level

Modeling Parameters

- Elastic Shell Element
  - Linear Elastic Element used for diaphragms
  - In-plane behavior based on membrane shell, out-of-plane based on elastic beam
- General Wall Element
  - Nonlinear Fiber Element typically used to model walls
  - Can Capture vertical axial/bending, horizontal axial/bending, and shear behavior



Fiber Section for P-M Behavior



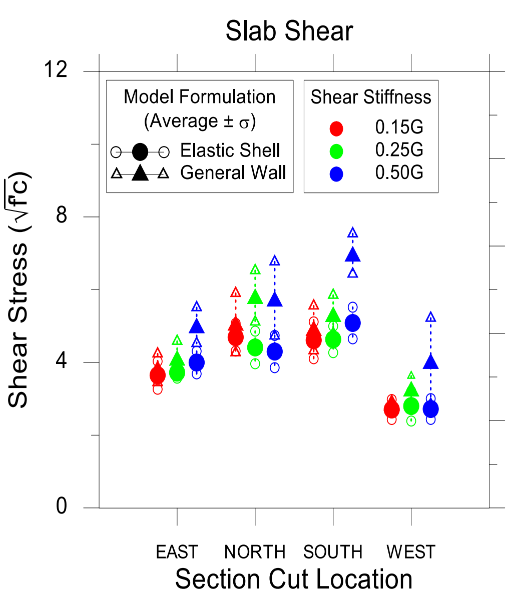
Typical Diaphragm Demands

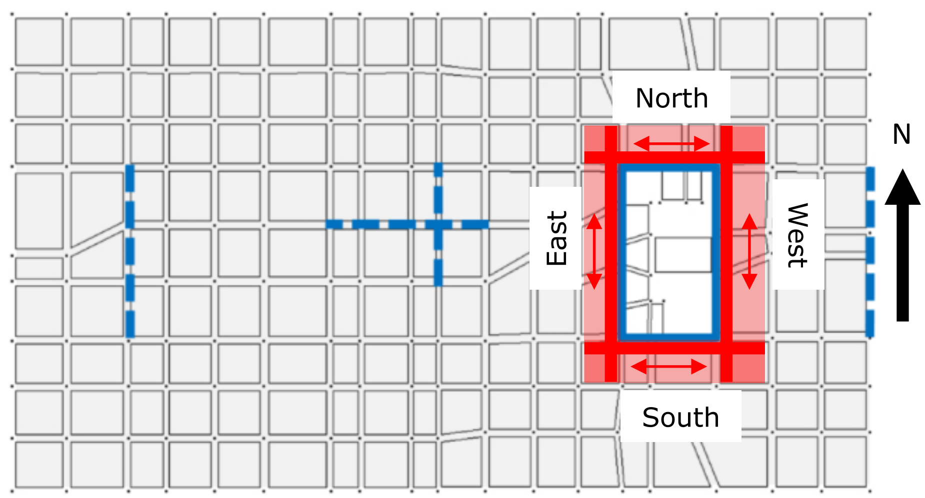
Typical Demands

- Demands used in typical engineering design
  - Drag Force
  - Shear Force
  - Chord Force
- Investigate sensitivity of demands to model configuration and effective shear stiffness

Slab Shear Demands

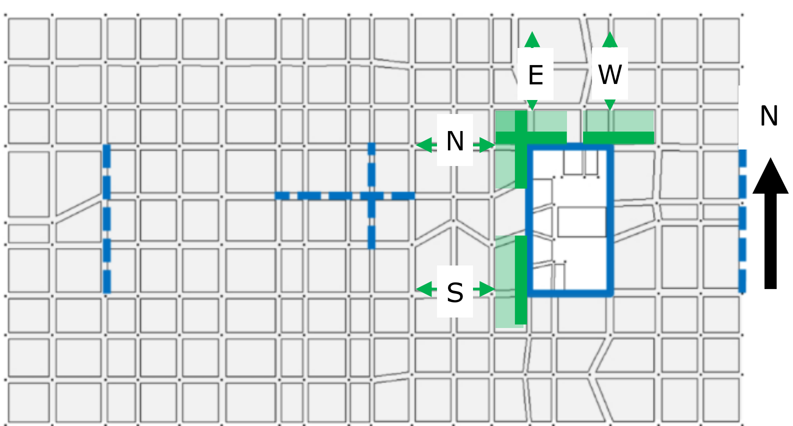
- Use of general wall element reports higher forces
- Effective shear stiffness show varying trends

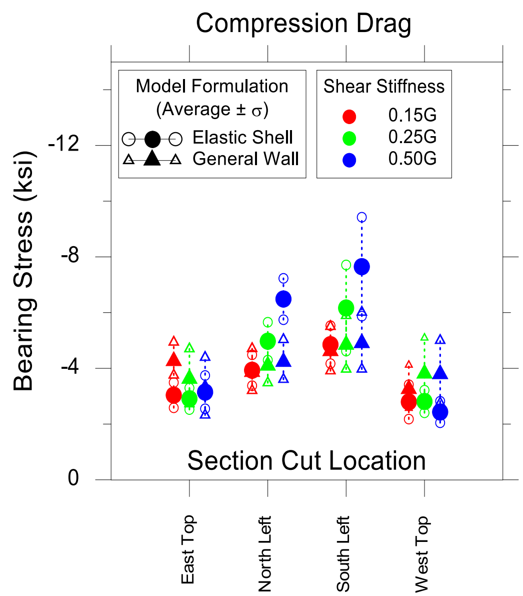


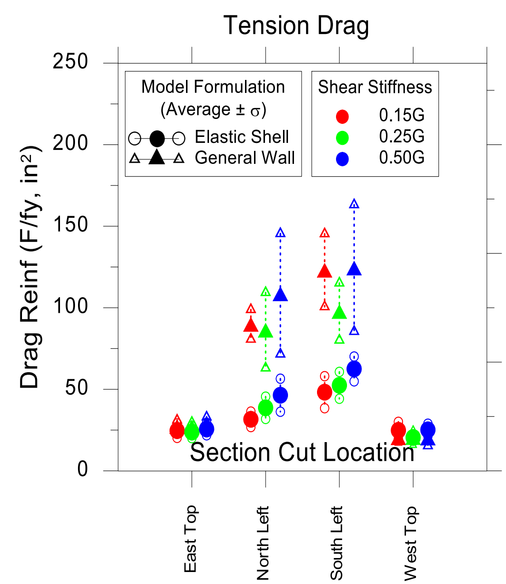


Drag Force – Compression Demands

- General Wall reports higher forces for tension
- Elastic shell reports higher forces for compression
- Elastic and general wall approximately the same for areas that don’t experience force transfer

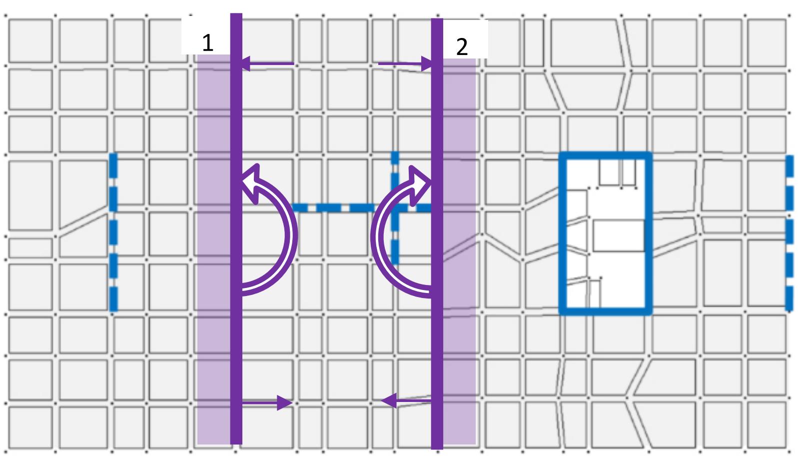


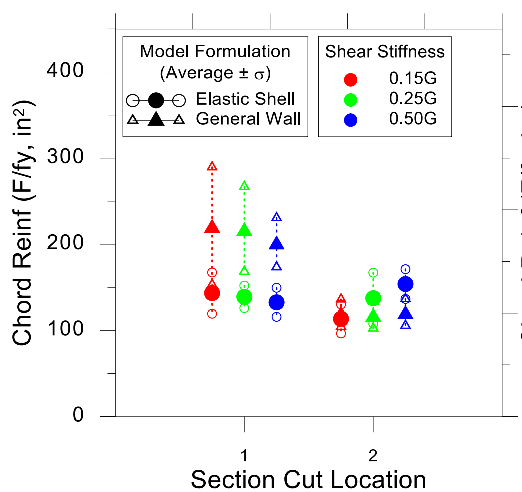


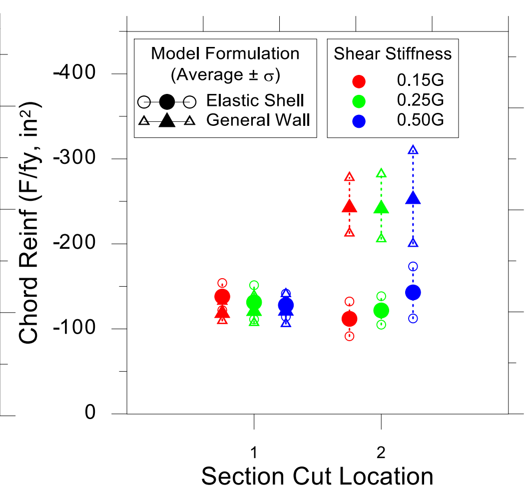


Chord Force Demands

- Different trends between positive and negative moments



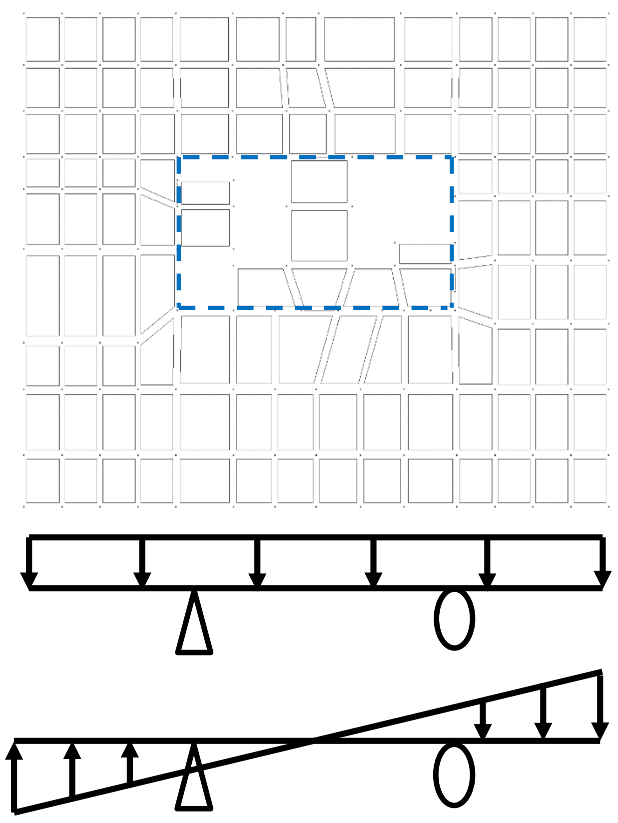




Comparison of Perform 3D vs. Simplified Calculation Methods

Comparison of Perform 3D vs. Simplified methods

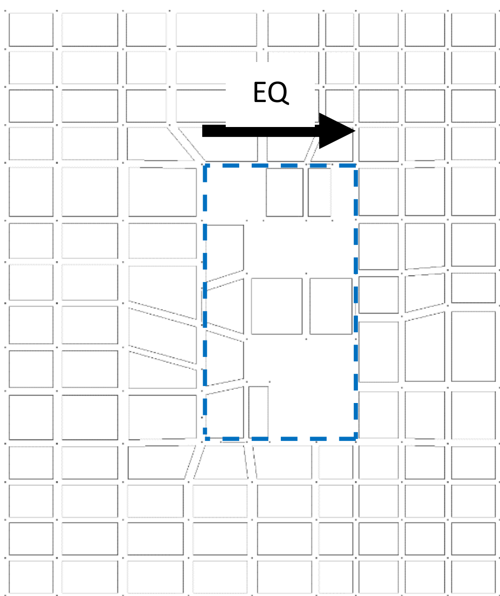
- Compare Perform 3D forces with forces from using Beam analogy
- Use forces from ASCE7 ELF and floor acceleration response from FE analysis
- Investigate effect of including torsion into simplified method

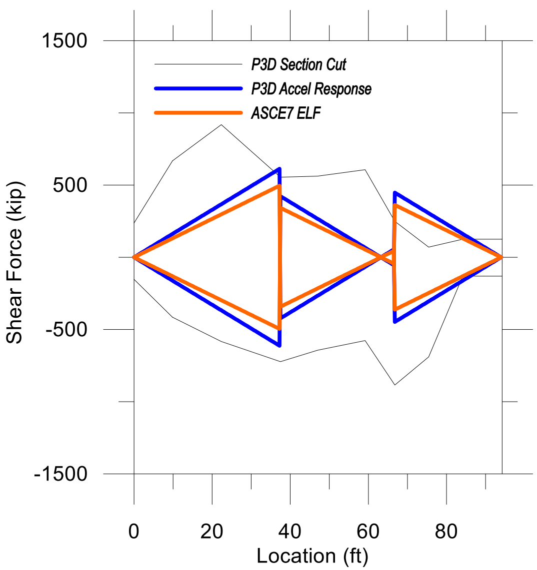


Force Diagrams with Translation Only

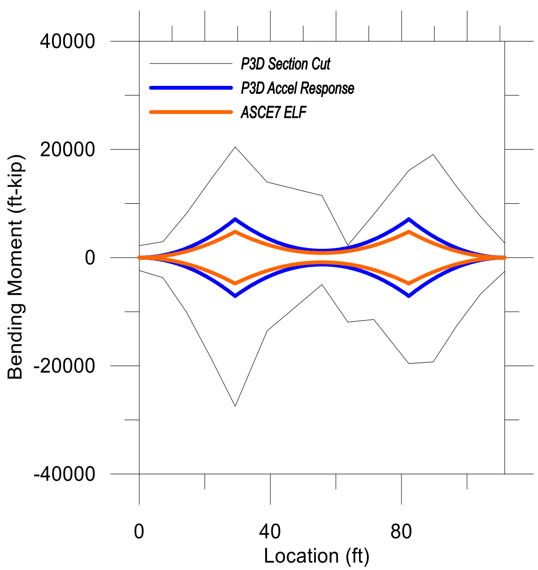
Tower Level: East-West Direction

- Beam Analogy underestimates forces from FE analysis





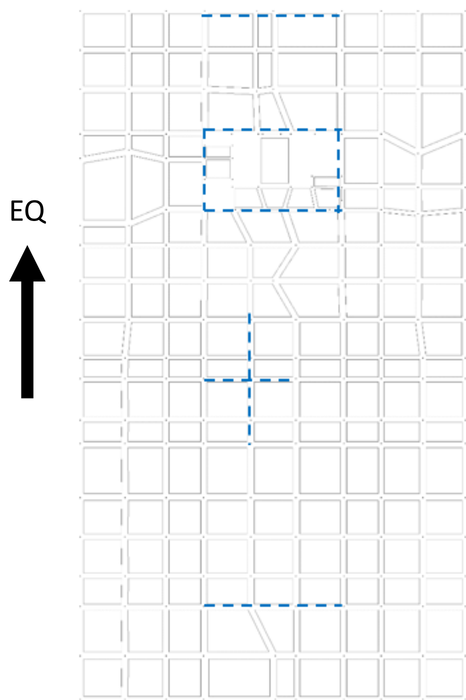
Shear Force



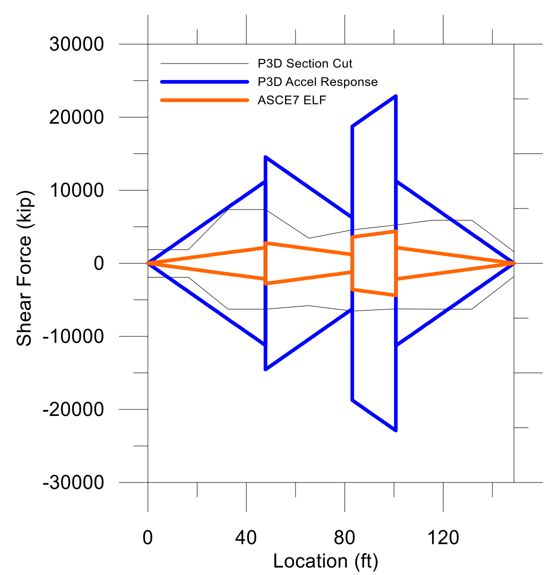
Bending Moment

Transfer Level: East-West Direction

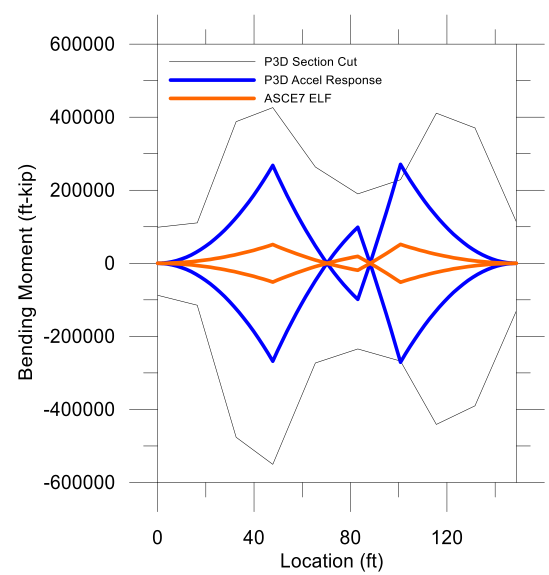
- Shear Forces overestimated, bending moment underestimated



Shear Force



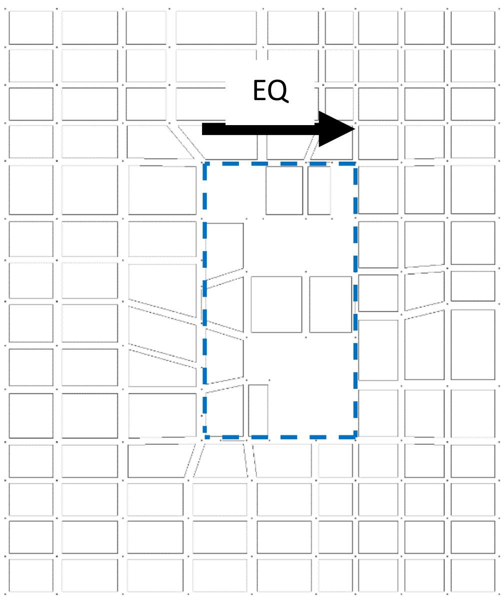
Bending Moment



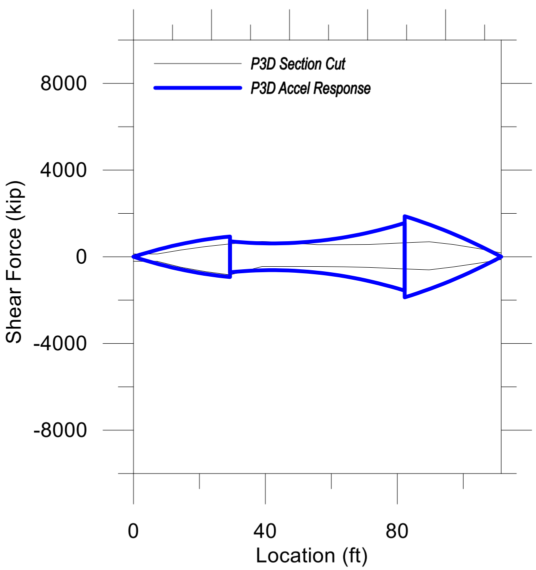
Force Diagrams with Translation and Rotation

Tower Level: East-West Direction

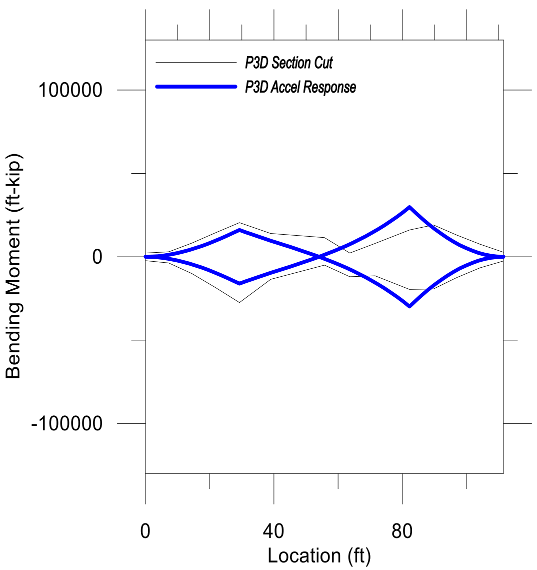
- Addition of rotational acceleration closed gap between simplified method and FE analysis



Shear Force

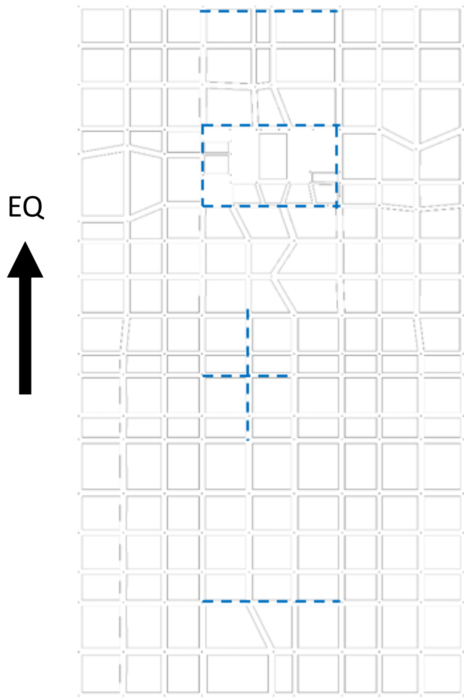


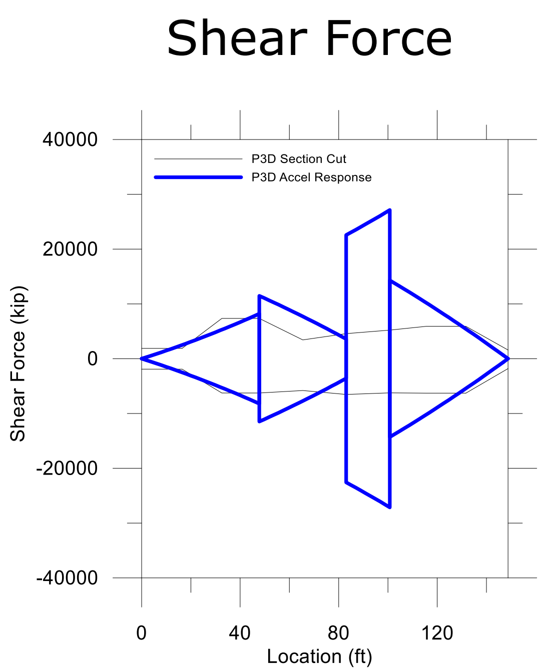
Bending Moment

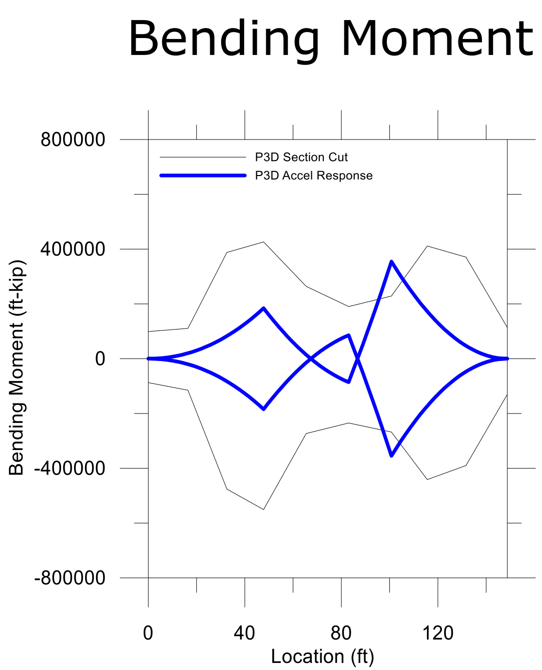


Transfer Level: East-West Direction

- Addition of rotational acceleration had small effect







Summary and Conclusions

- Sensitivity of demands to modeling formulation are inconsistent.
  - Comparison between general wall and elastic shell elements as well as shear stiffness sensitivity dependent on cut location and type of force extracted.
- Beam analogy for tower level unable to estimate Perform 3D forces
  - Forces underestimated with only translational response considered
  - Inclusion of rotational response closes gap between envelopes, slightly overestimating FE forces
- Hand calculations for transfer level shear tend to overestimate while bending moment is underestimated with translation only
  - Inclusion or rotational response has little to no effect on the envelopes