WCTE Auckland New Zealand
15 - 19 July 2012
World Conference on Timber Engineering

Hybrid Wood and Steel System: Overstrength and Ductility

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Project Description

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Goal:

Analyse and provide guidelines for the design of the hybrid seismic force resisting system, steel moment frames with infill wood shear walls

Hybrid System of Interest:

- Hybridize steel and wood into a vertical seismic force resisting system.
- Focus on steel moment frames with a wood infill wall system
- Address material incompatibilities with special attention to hydroscopic properties in wood
- Provide values for equivalent static seismic design of system

Hybrid System: Base Building

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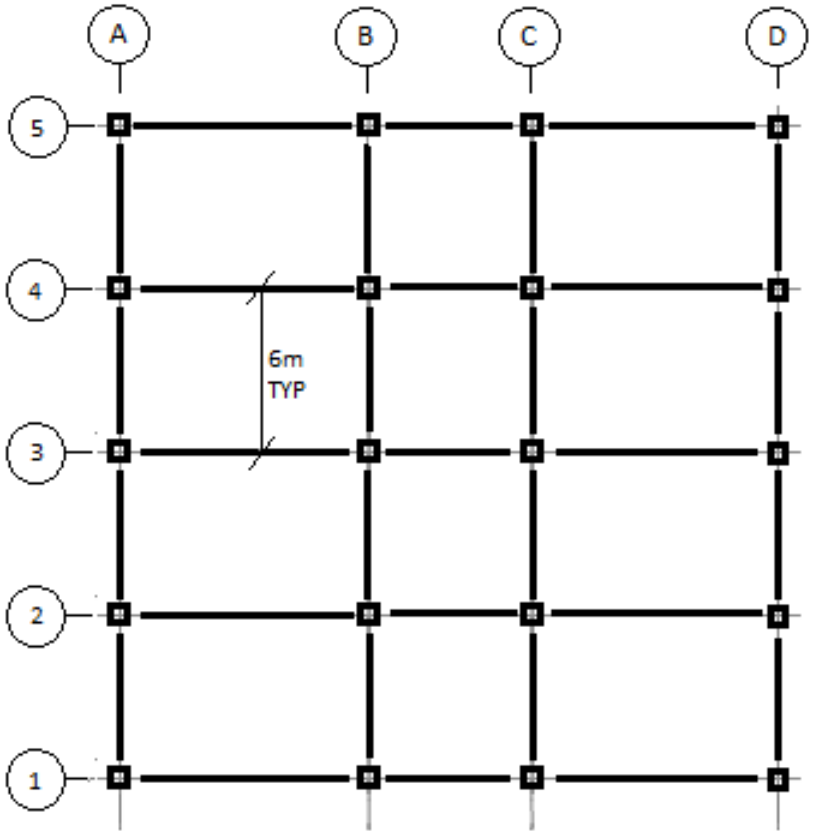
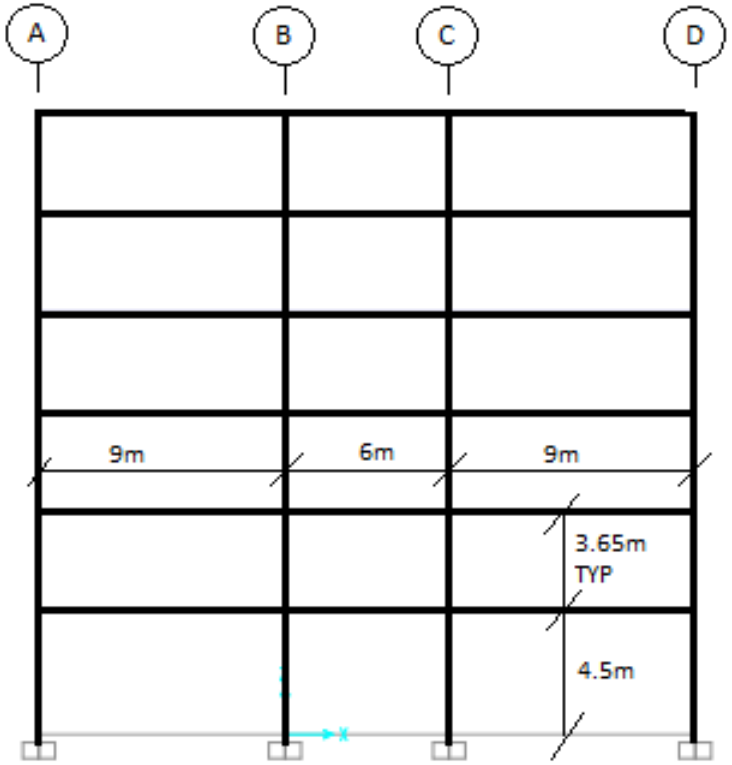
Building Plan



Frame Elevation



Hybrid System: Parameters

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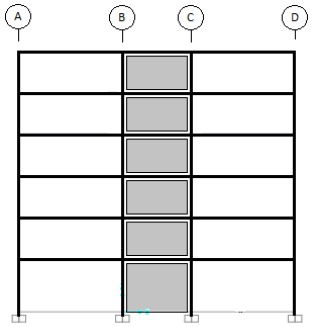
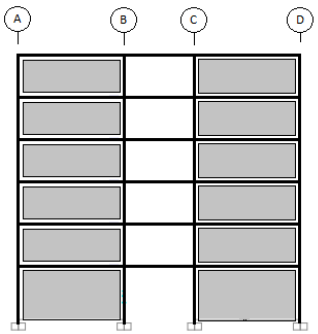
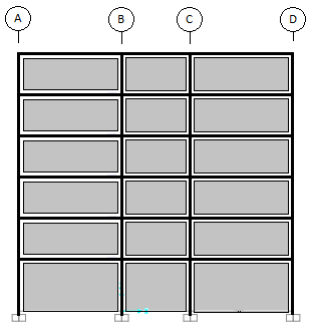
Parameter	Options		
Infill Wall Types	CLT shear walls	Midply shear walls	
Ductility	Limited Ductility	Ductile	
Storeys	9	6	3
Braced Bays	One Bay	2 Bays	3 bays
Bracket Properties	Gap between infill and steel frame		



Infill Case 1



Infill Case 2

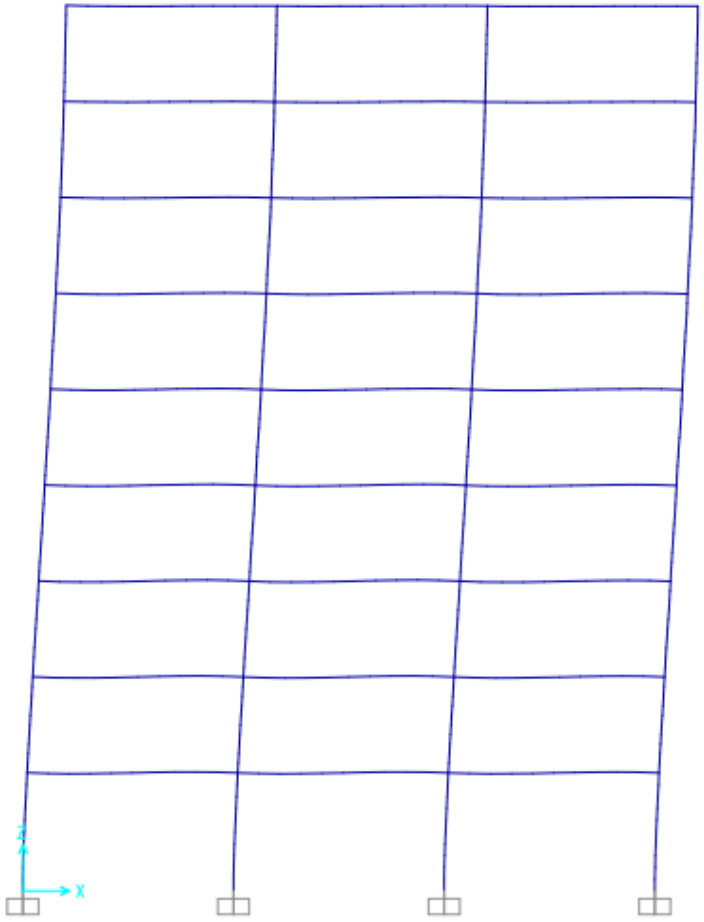


Infill Case 3

Bare Frame Design

- Steel moment frame to be designed based with NBCC ductility requirements
- Infill walls to be added and compare the response of the frame and the response of plain wood walls

Ductility Type	Steel Moment		Wood	
	Rd	Ro	Rd	Ro
D	5.0	1.5	2.0	1.7
MD	3.5	1.5		
LD	2.0	1.3		



Infill Walls: Midply Shear Walls

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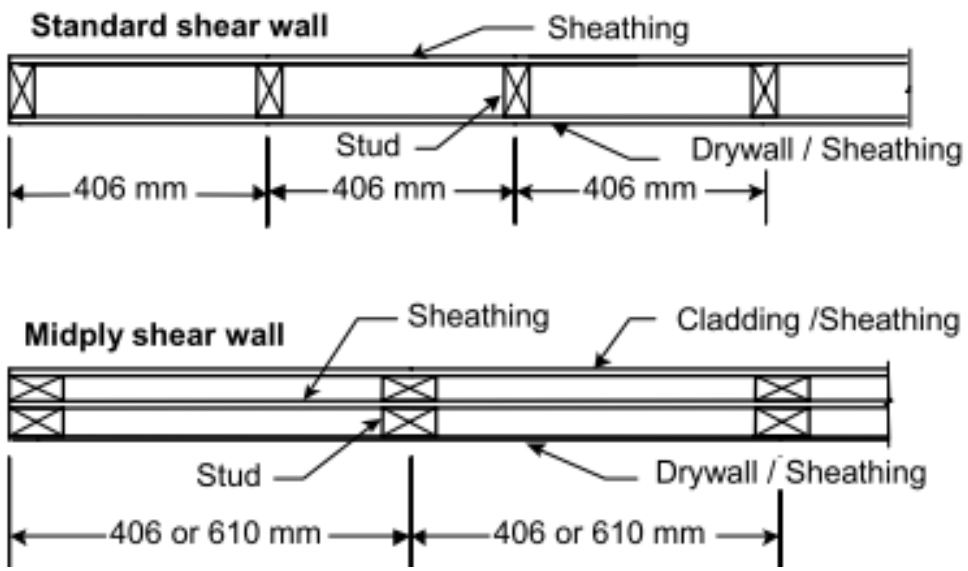
Midply walls have higher strength compared to standard plywood shear walls

- Nails in double shear
- Nail head does not pull through sheathing
- Increased nail edge distance

Failure of walls occurs through buckling of studs



Infill Walls: CLT Walls

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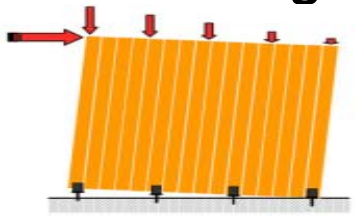
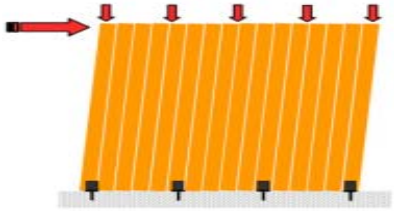
- Approximated as elastic perfectly plastic with plasticity model
- Elastic properties determined using composite theory
- Strength limits determined from product data
- Plain CLT systems show all deformation in connectors
- Confinement from surround frame may cause deformation in the panel

	Parallel to grain	Perpendicular to grain
ELASTIC PROPERTIES		
Elastic	7800 MPa	4600 MPa
Shear	250 MPa	
STRENGTH		
Tension	16.5 MPa	
Compression	24 MPa	
Crushing	30 MPa	
Shear	5.2 MPa	

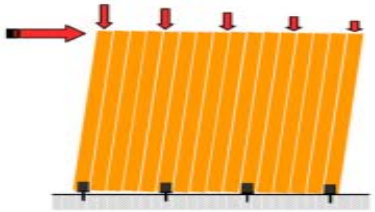
Pure Rocking



Pure Shear



Shear and Rocking



Connection between Wall and Frame

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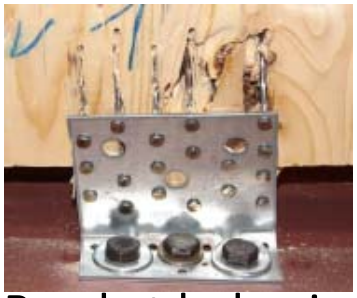
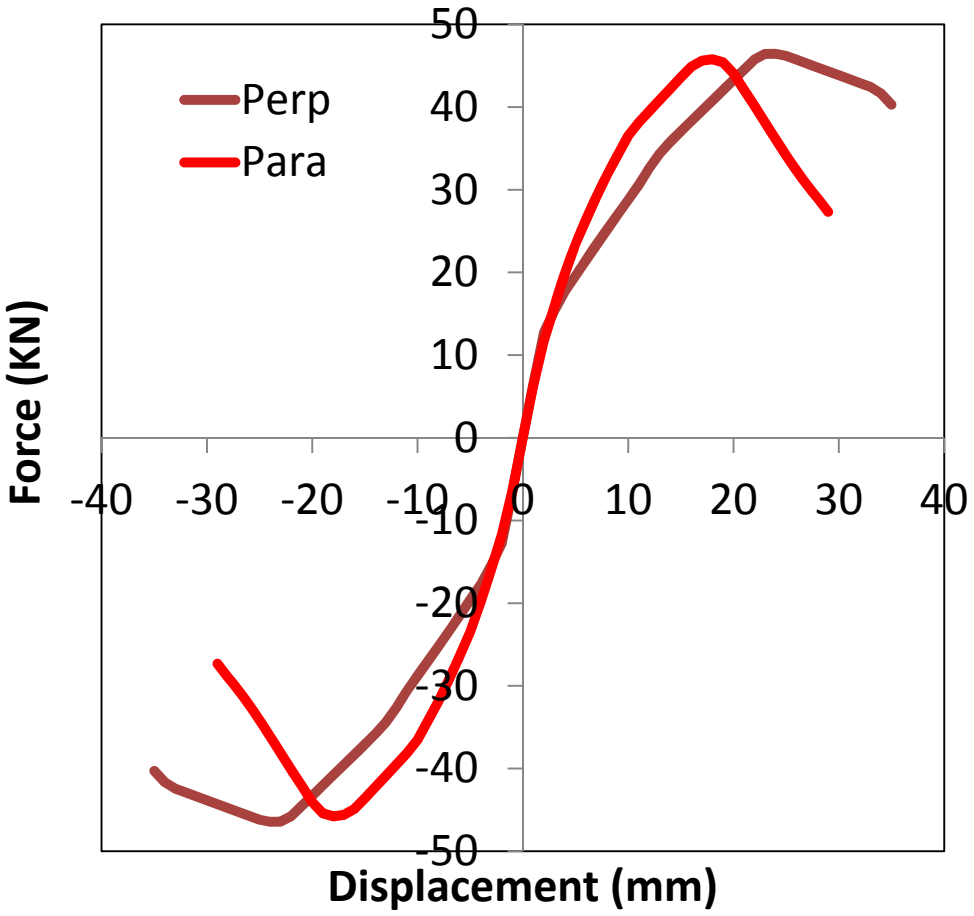
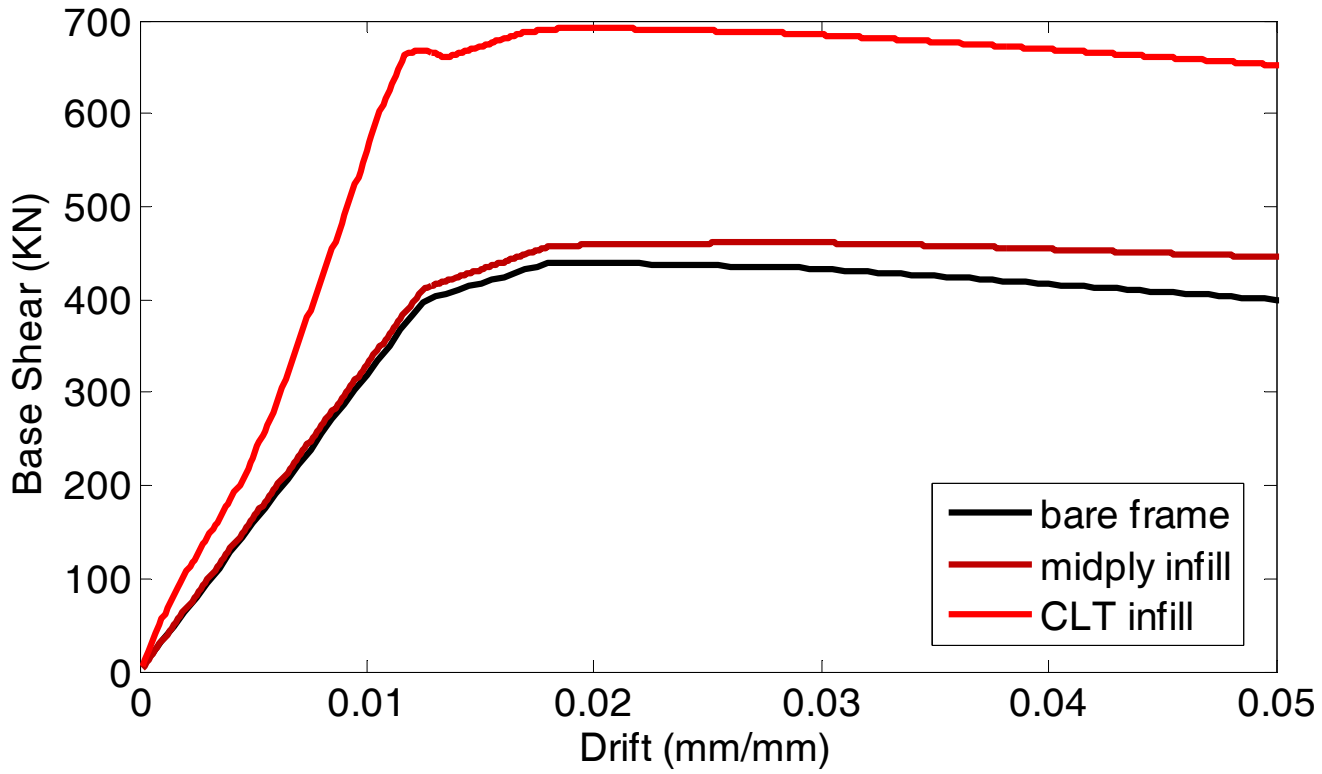
- Nailed bracket connection developed for CLT walls



- Bracket behaviour is independent in different directions
- Confinement also provided along edges of panel to provide confinement using "gap" elements

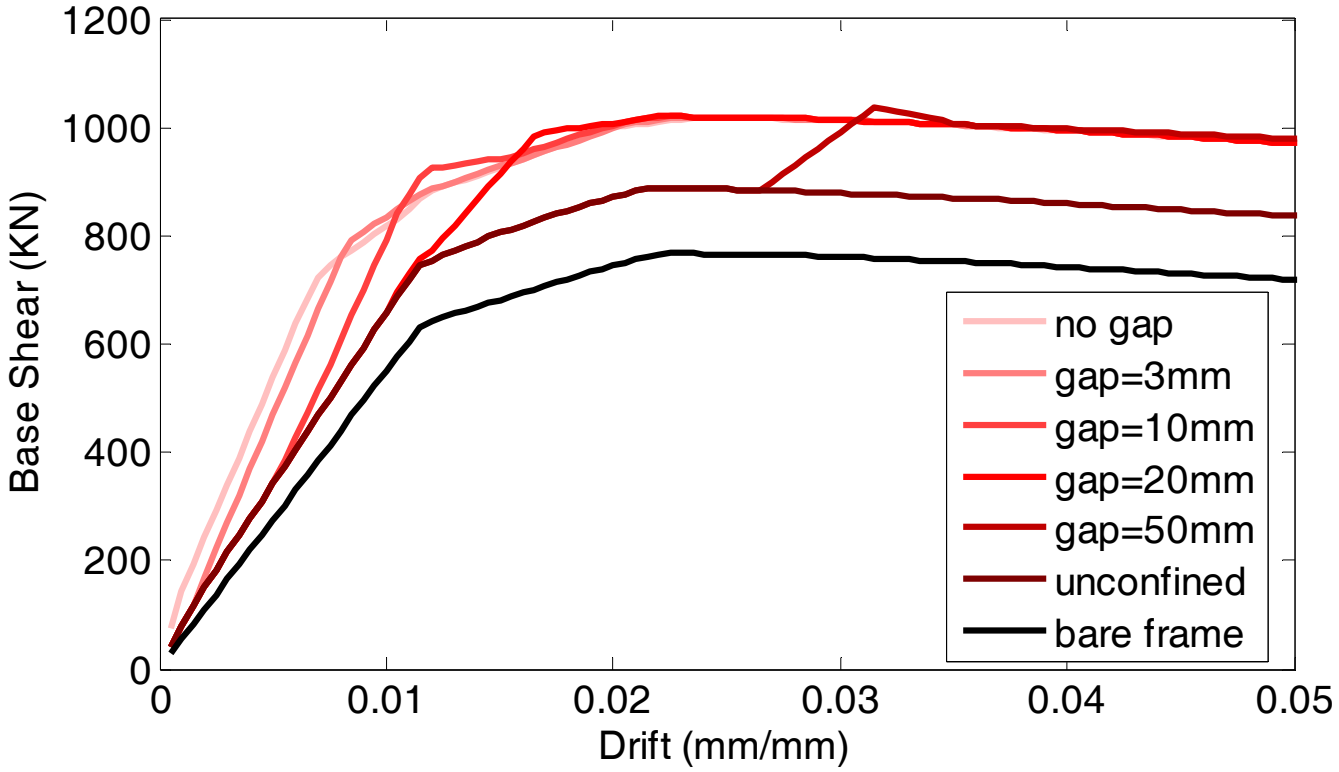


Pushover Results



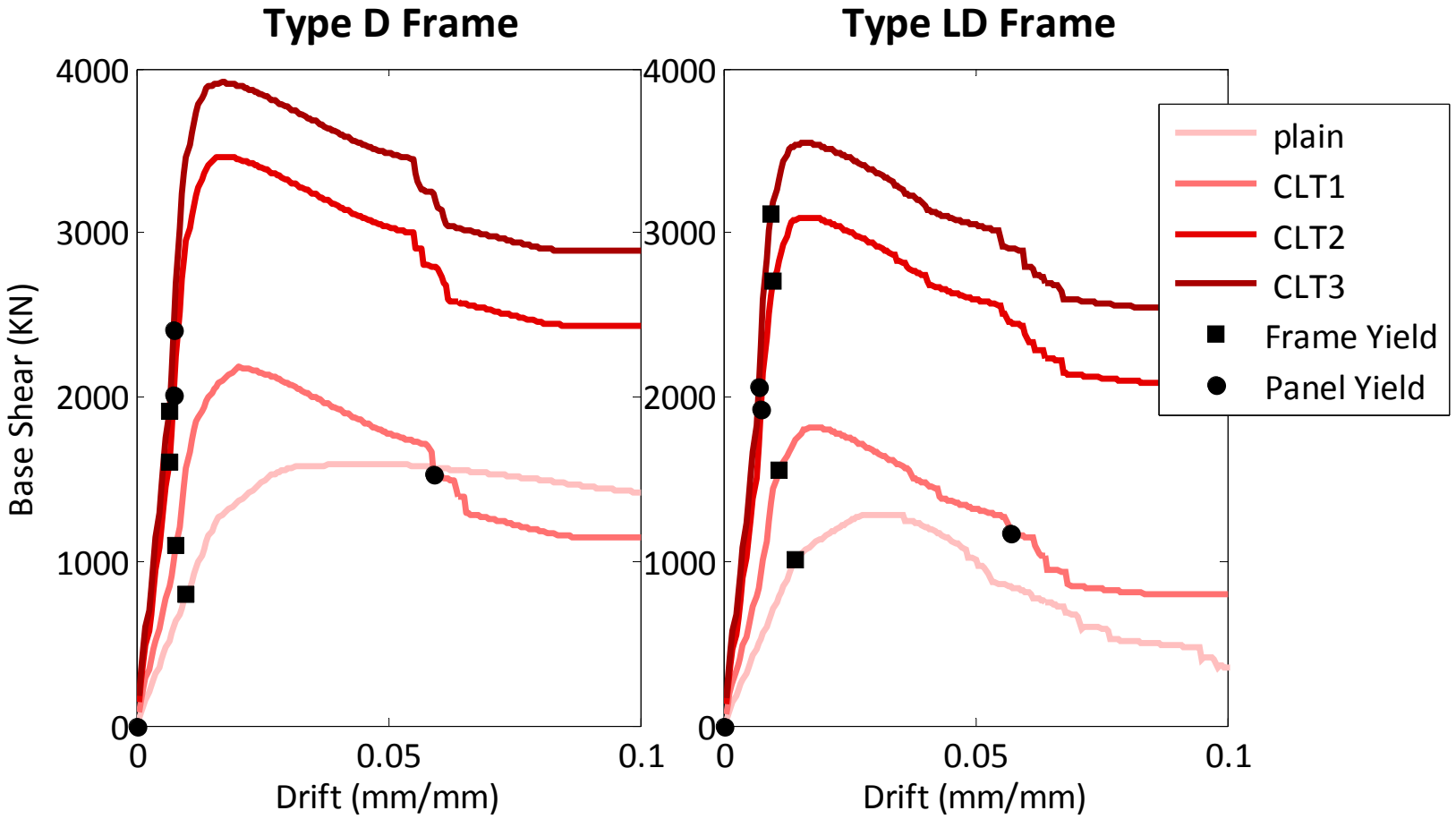
Effect of Infill Panel Type: Single Storey Single Bay Frame

Pushover Results



Effect of Gap Size between Infill Panel and Frame: Single Bay Single Storey Frame

Pushover Results



Effect of Moment Frame Ductility: 3 Storey Steel for all Infill Configurations

Pushover Results

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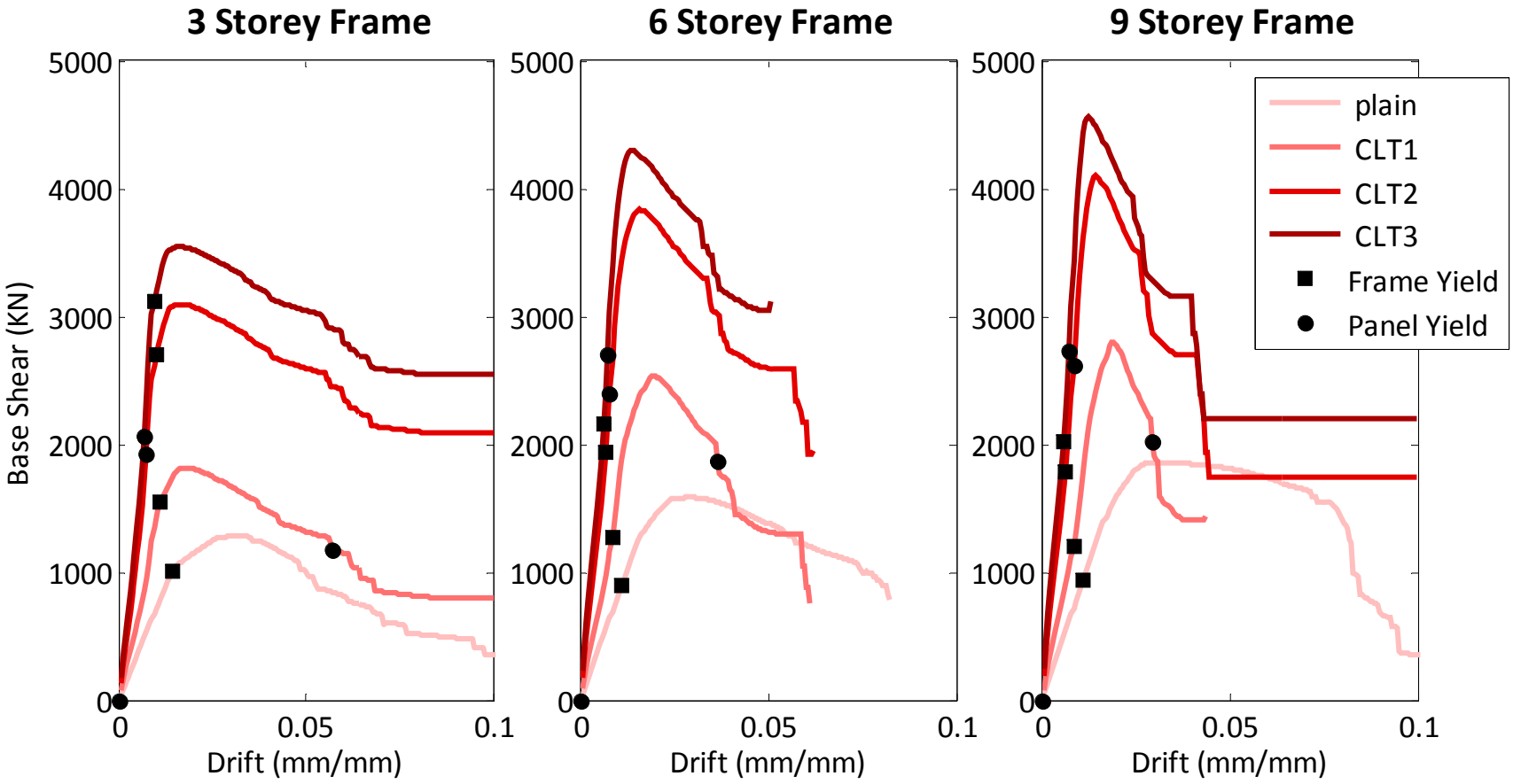

Effect of Number of Storeys: Limited Ductility Steel Moment Frames for all Infill Configurations

Pushover Results

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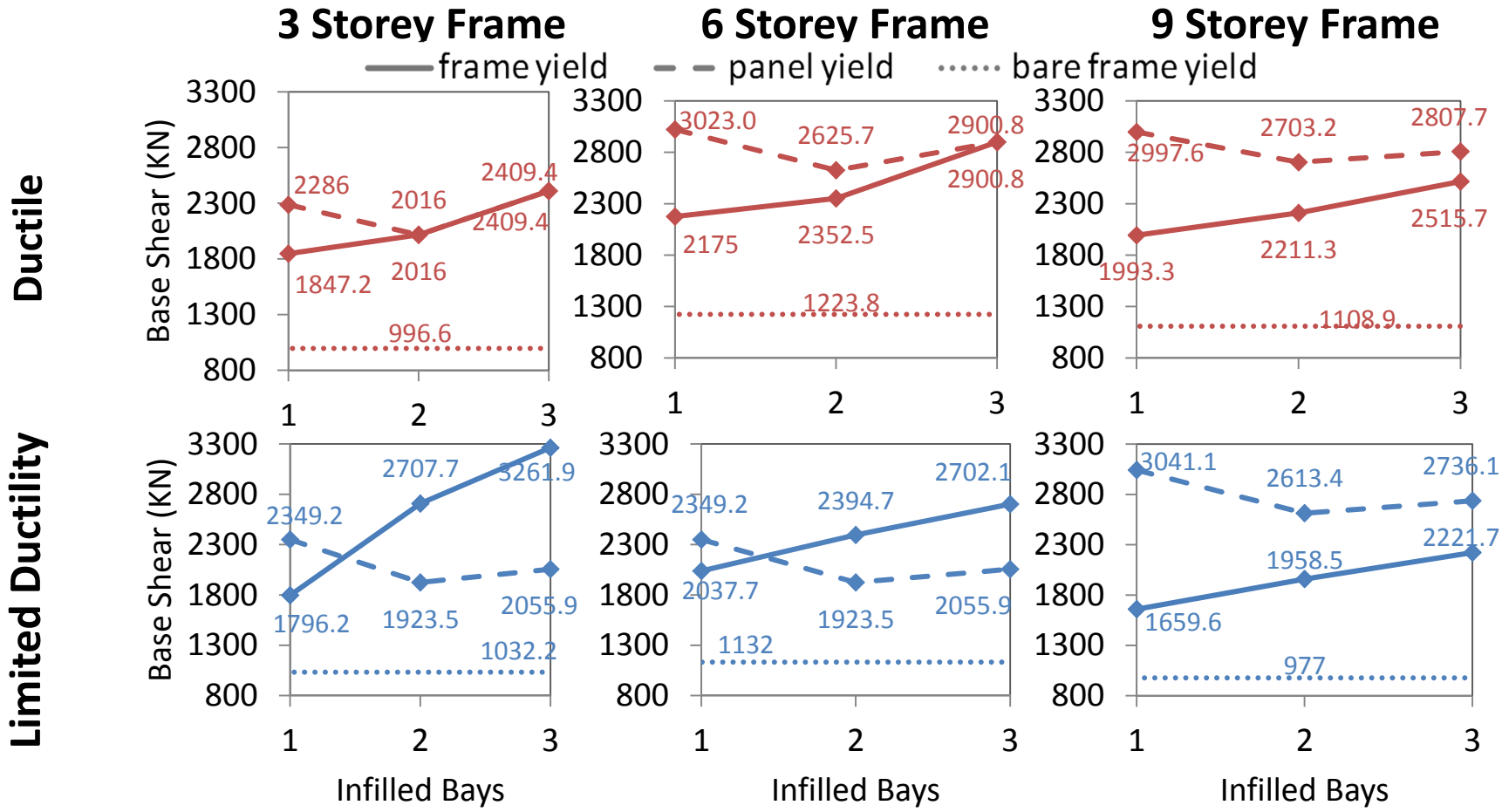

Comparison of Frame and Panel Yield for all Frames and Infill Configurations

NBCC Seismic Factor Definition

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Overstrength (R_o or Ω)

- Overstrength is the ratio of the design load to the ultimate load of the system
- Looking at the innate overstrength in this type of system, the design load is taken as the load at first yield

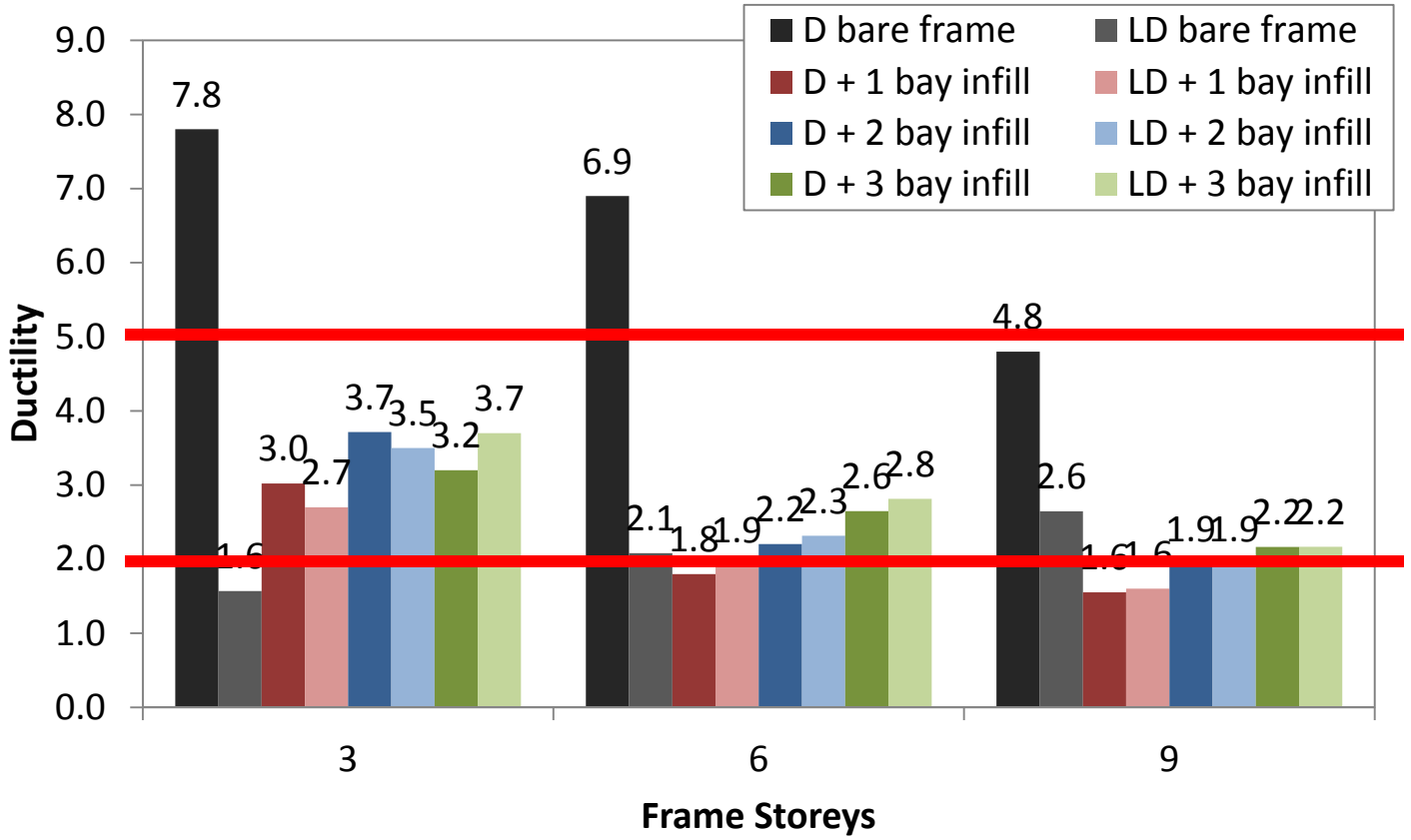
$$\Omega = R_o = \frac{V_{max}}{V}$$

Ductility (R_d or μ_T)

- Ductility is the ratio of the displacement at the ultimate load to the displacement at failure
- Failure is taken as an 80% reduction in strength after the ultimate load has been acheived according to FEMA P695

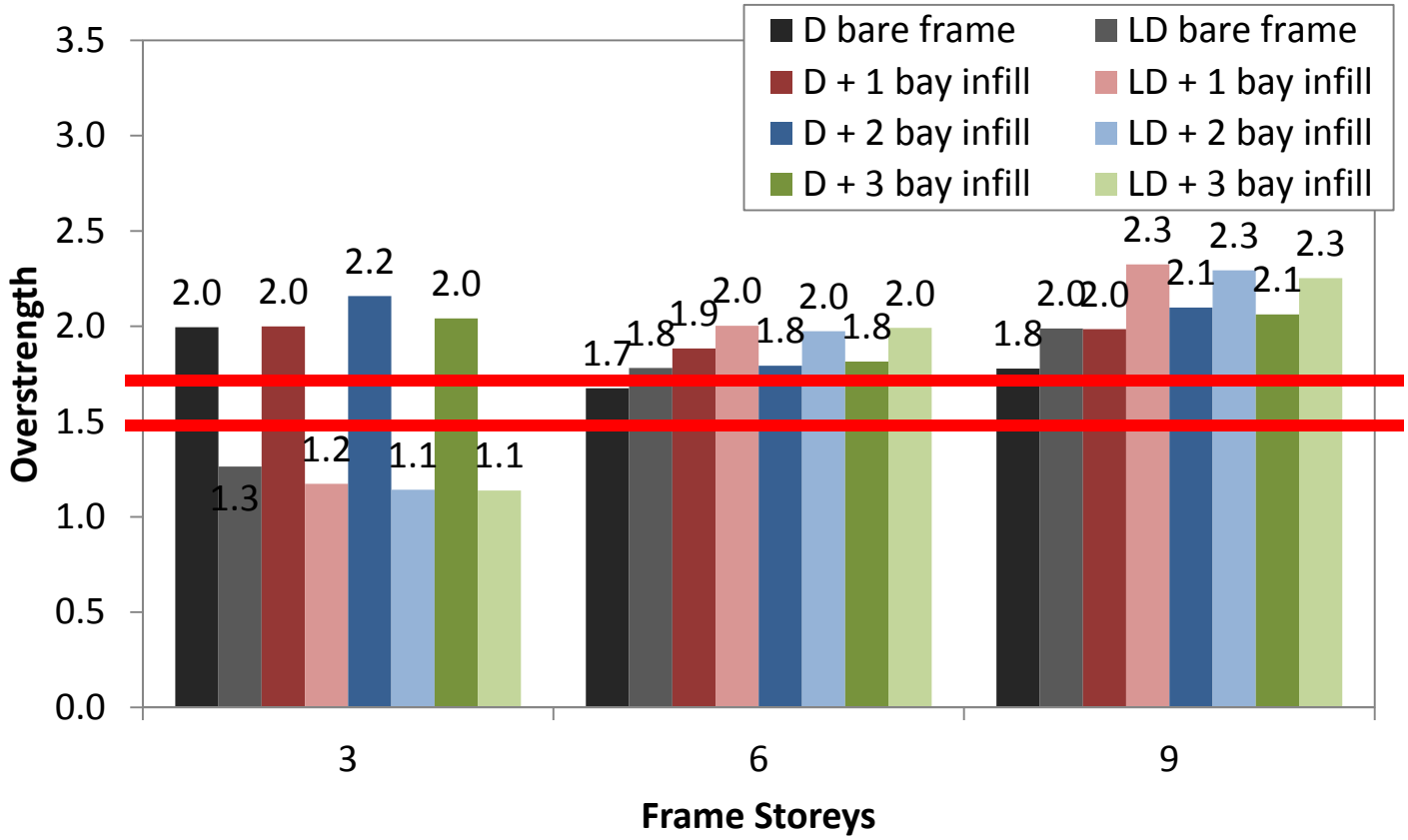
$$\mu = R_d = \frac{\delta_u}{\delta_f}$$

NBCC Seismic Factors



Ductility Factor for all Frames

NBCC Seismic Factors



Overstrength Factors for all Frames

Future Work

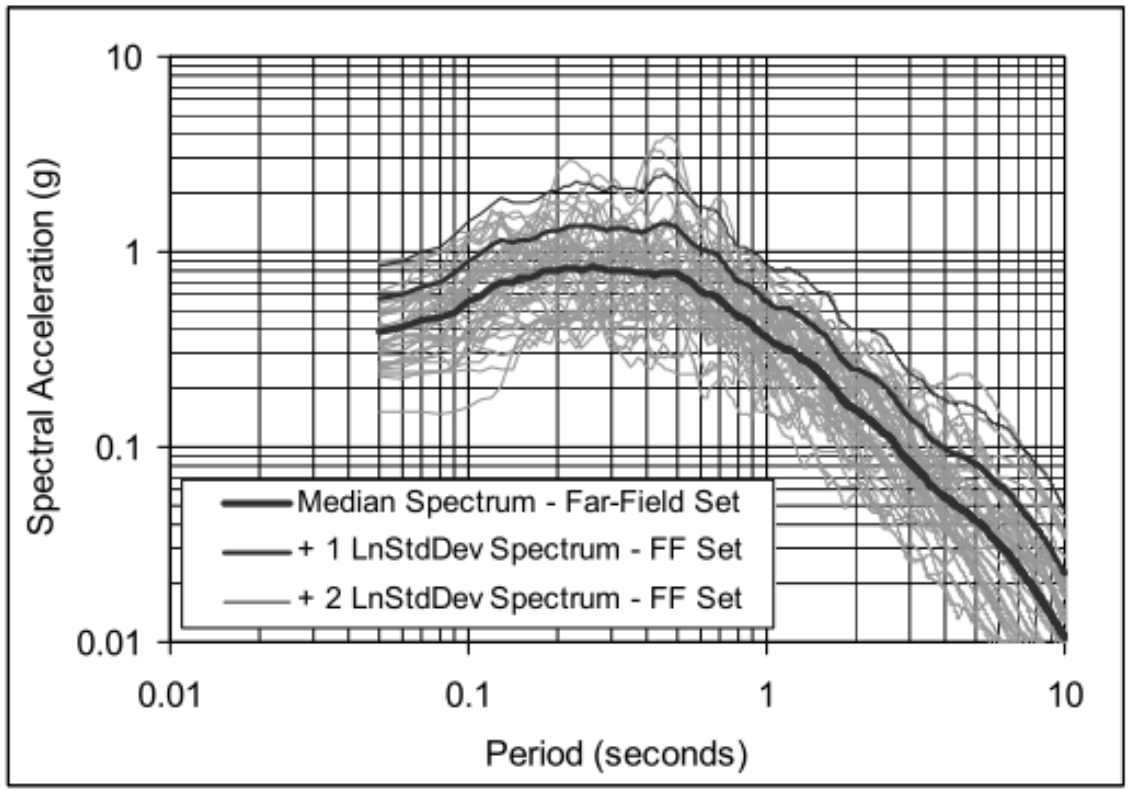


Figure A-3 Response spectra of the forty-four individual components of

- FEMA P695 guidelines for dynamic analysis
- Partial Incremental dynamic analysis
  - 22 'Far-Field' ground motions

Acknowledgements

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