SEISMIC RETROFIT OF A NON-DUCTILE CONCRETE TOWER USING PERFORMANCE BASED APPROACH

Saiful Islam, Ph.D., S.E.

President, SAIFUL/BOUQUET Structural Engineers

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NORTHRIDGE 20 SYMPOSIUM

www.northridge20.org

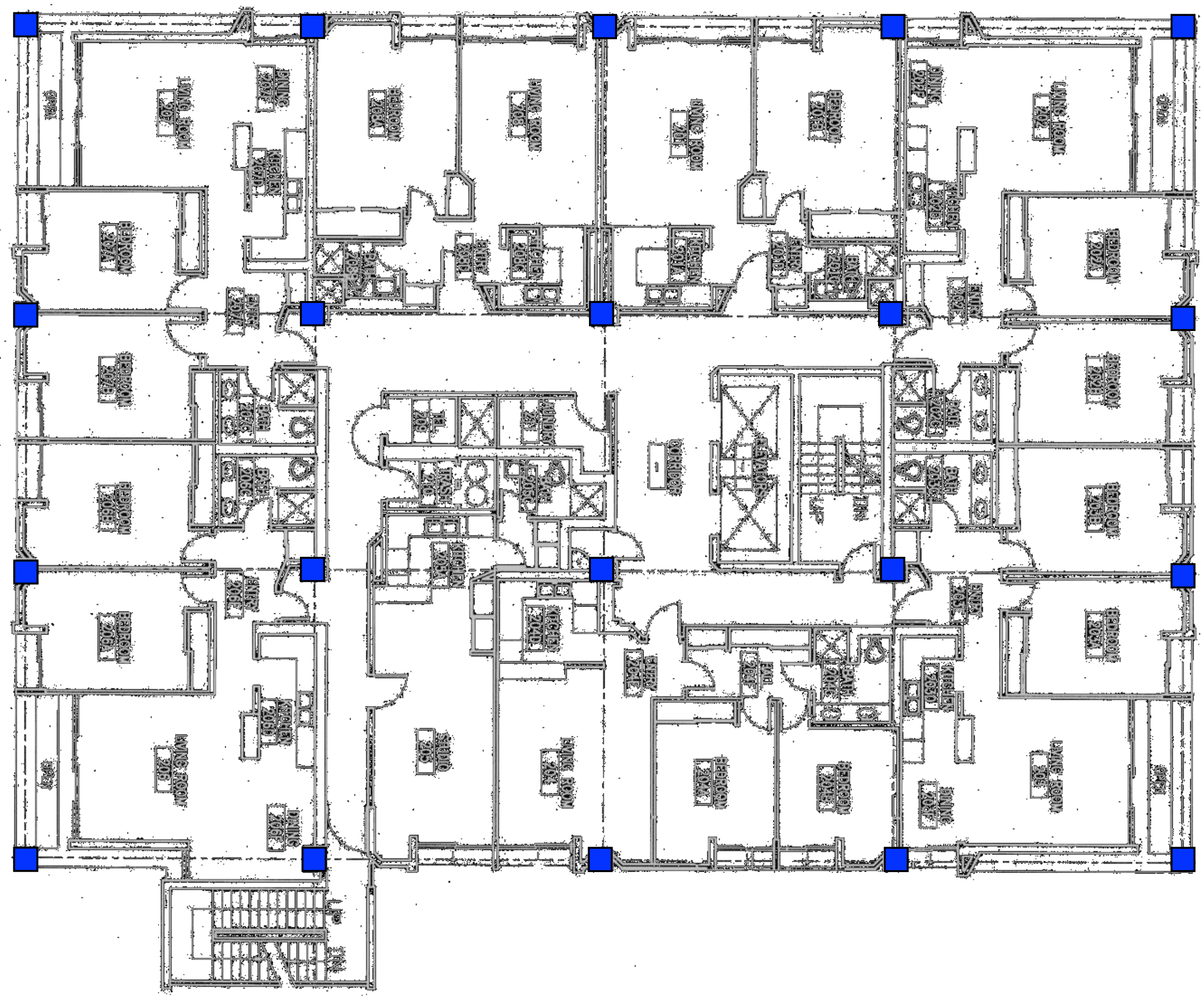
Northridge Earthquake

Existing Building Description

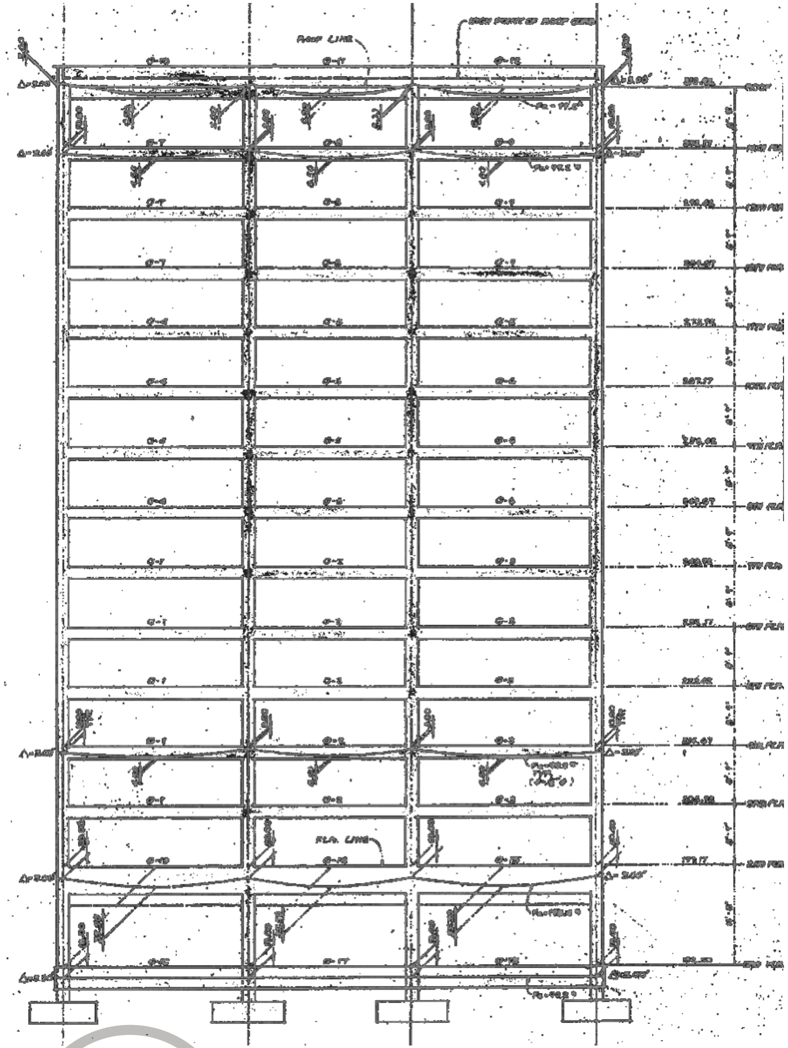
- 14-story Conc. Residential Tower
- Built in 1972 (UBC 1965)
- Constructed of Lt.-Wt. Concrete
- 8-inch thick P/T floors
- Perimeter P/T Non-Ductile Concrete Moment Frames

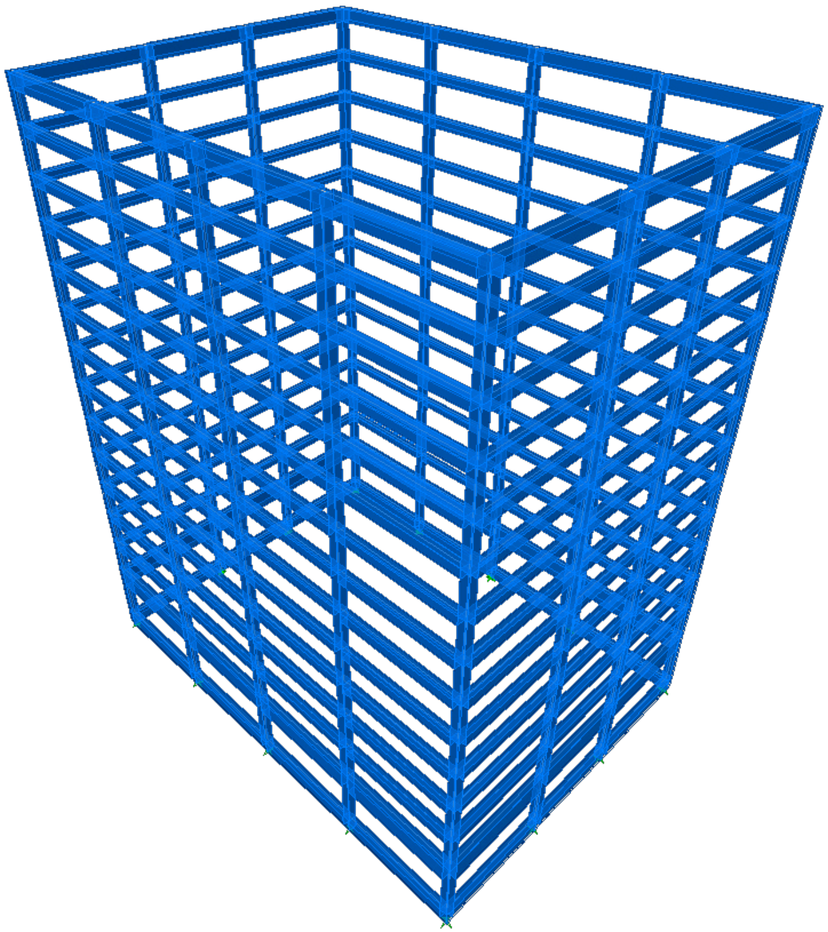
Webb Tower, University of Southern California

Existing Floor Plan



Existing Frame Elevation





Seismic Concerns

- Non-Ductile Concrete Moment Frames
- Exist’g Beams heavily reinforced but w/ minimal confinement
- Severe post-yield strength / stiffness degradation
- Story Drift Excessive for a Non-Ductile Frame Bldg.
- Excessive Joint Shear

Seismic Strengthening Objective

FEMA 356 (ASCE 41) ***"Basic Safety Objective"***

475-yr Eq.	**=**	**Life Safety**
2475-yr Eq.	**=**	**Collapse Prevention**

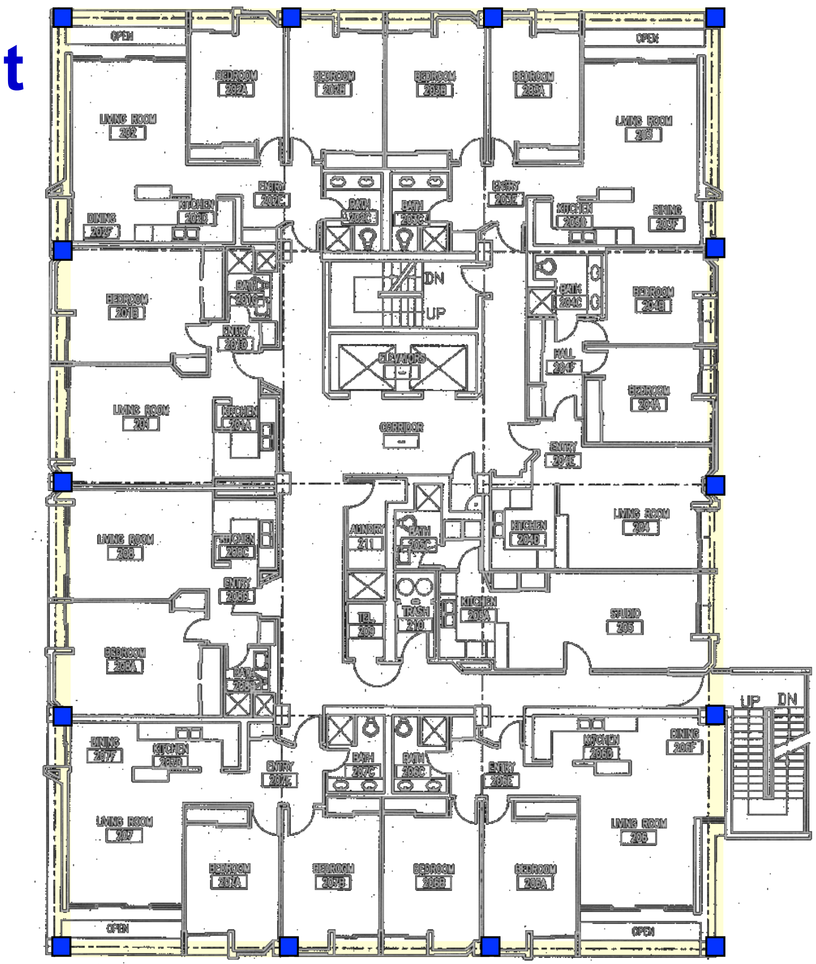
Design Objective & Challenges

- Reduce Reliance on Non-Ductile Concrete Frames
- Minimize Impact on Interior Layout
- Allow at least one window to each dorm room.
- Solution must be aesthetically acceptable

Multiple Structural Schemes Investigated

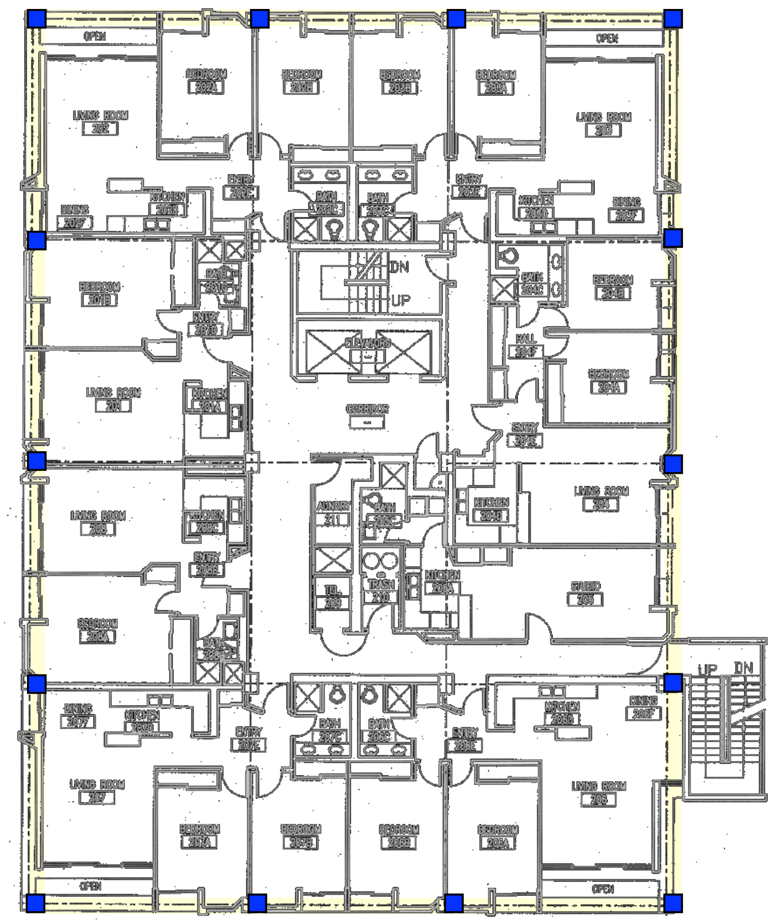
- ***Interior Schemes*** – **Ruled out early in the Design**
- ***Exterior Schemes Only*:**

  1. **Shear Wall Scheme**
  2. **Conventional Steel Brace**
  3. **Exterior Buckling Restrained (Unbonded) Brace Frame**

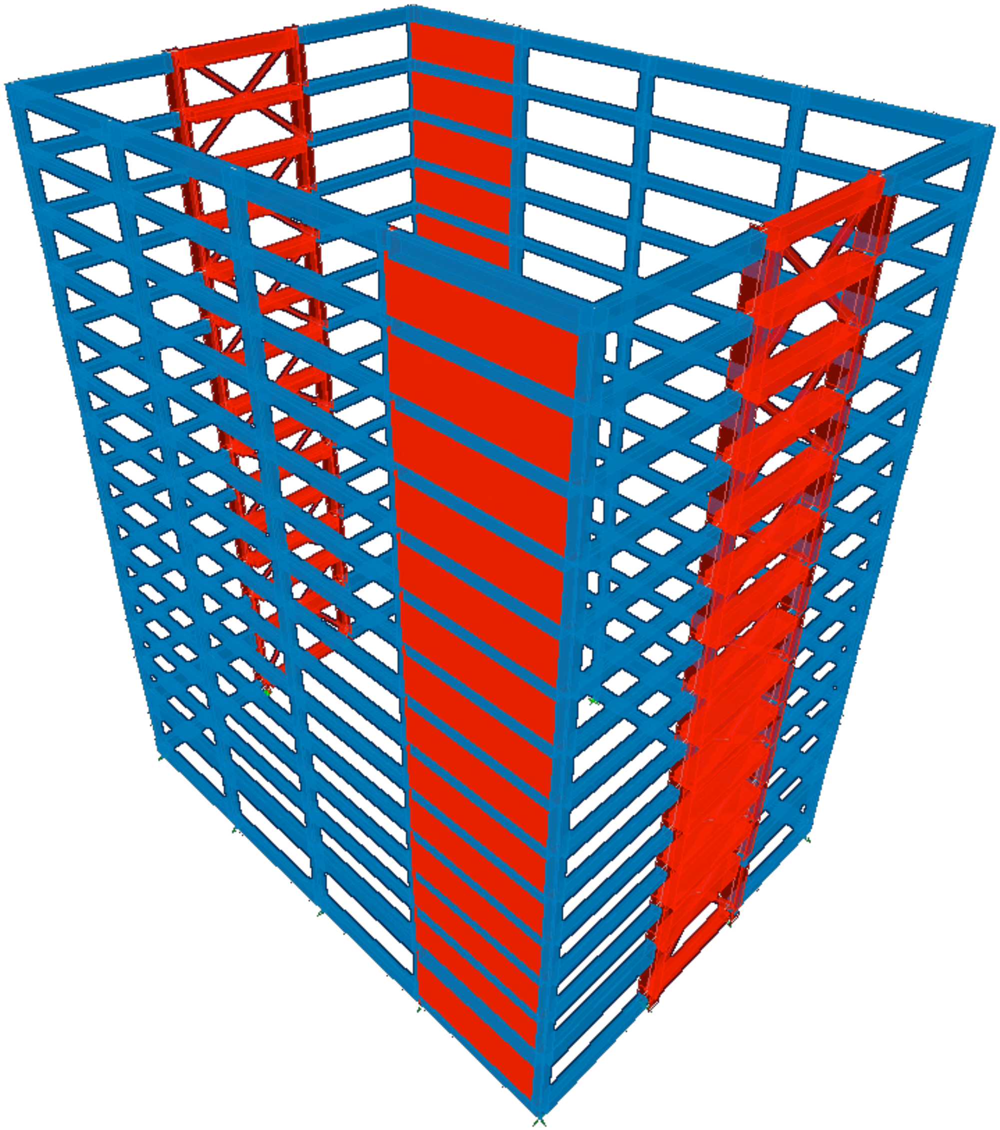


Advantages of Exterior Scheme

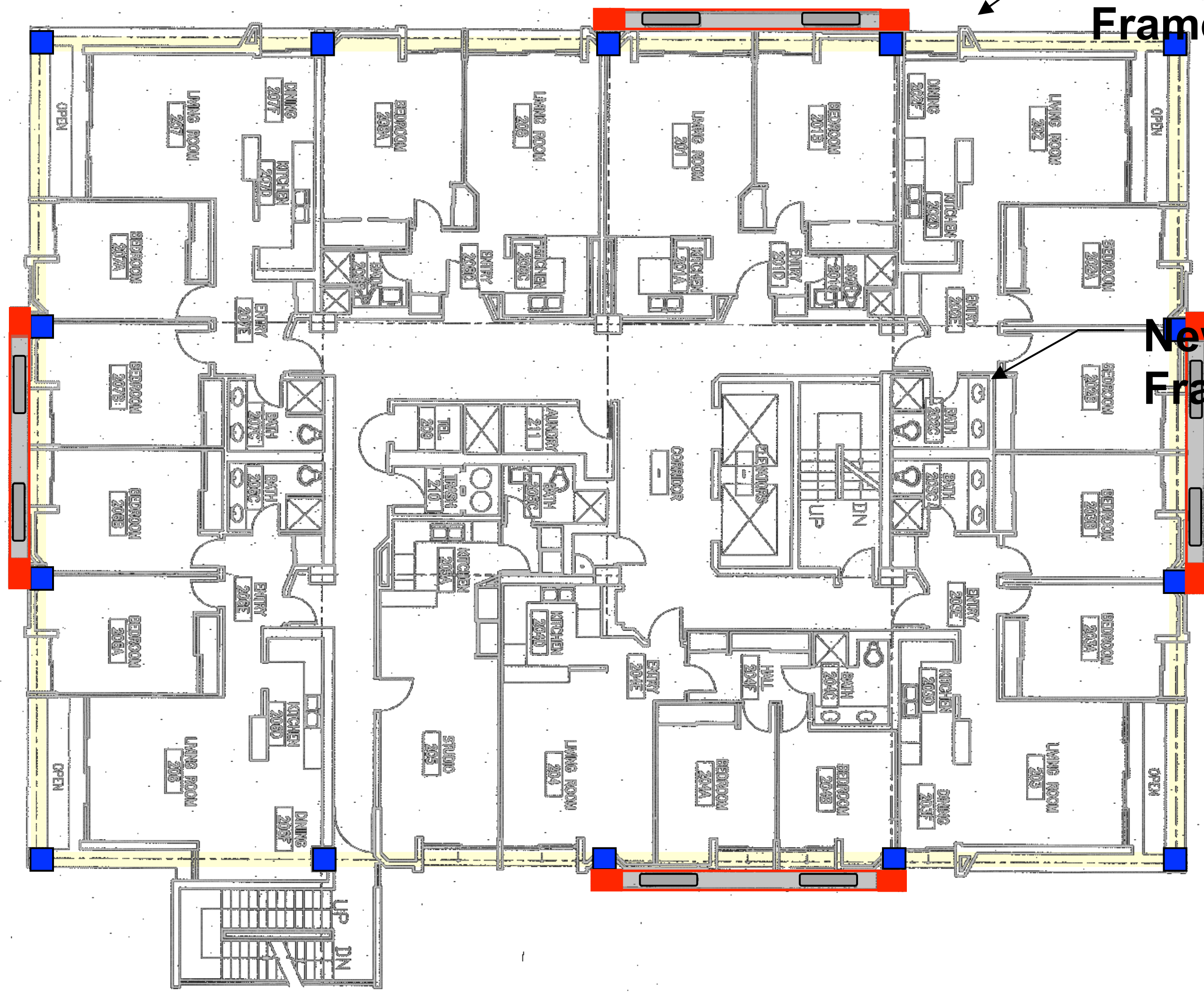
- Did not require reconfiguration of the rooms
- P/T tendons in the slab did not need to be located.
- Interior renovation work could occur concurrently with the exterior seismic work



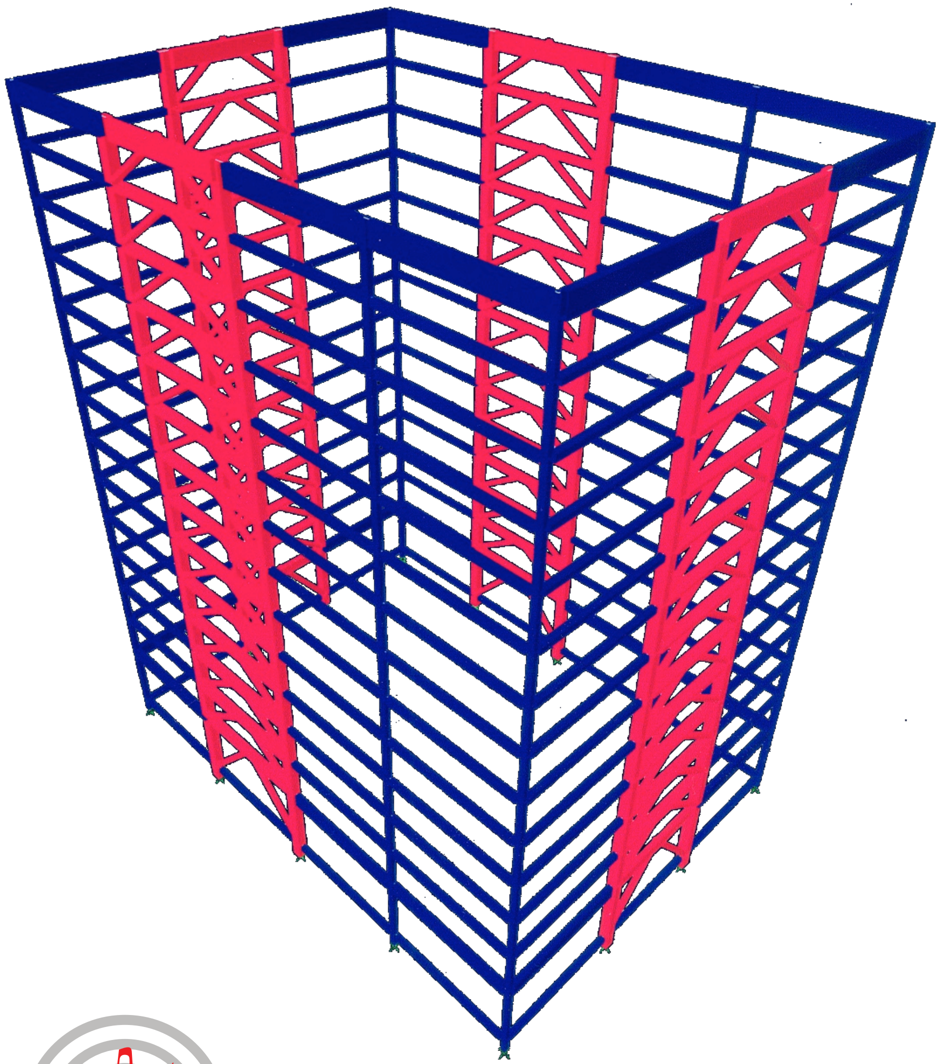
ETABS Model – Shear Wall Scheme



Unbonded Brace Frame Scheme



Buckling Restrained Brace Frame Scheme

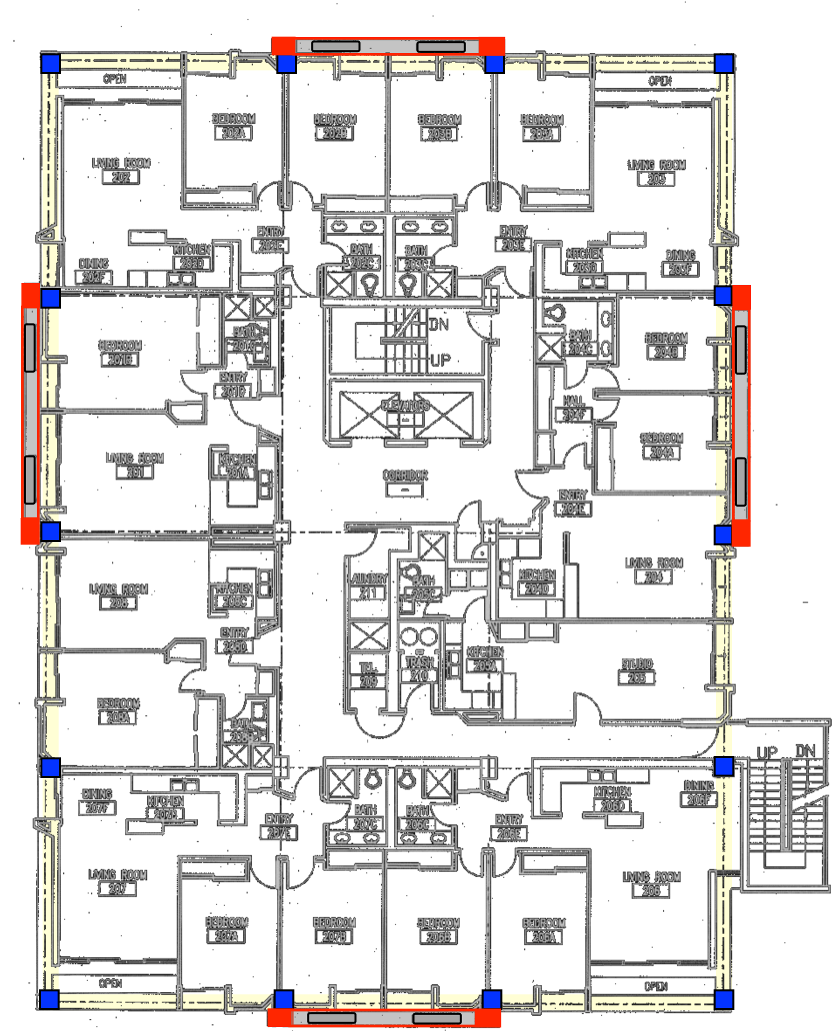


Why Buckling Restrained Braces?

- Stable Energy Dissipation Characteristics
- Non-Degrading Stiffness & Strength behavior
- Required less braces than conventional steel brace frame.
- BRB does not buckle. Because of exterior application, large deformations associated w/ buckling of conventional braces not an option

BRBF Retrofit Scheme

- New Cols: 20” x 30”
- New Beams: 20” x 22”
- BRB’s: 230-700 kip capacity.
- Enlarge Existing spread footings.



Design Approach

DESIGN:

Based on linear dynamic response spectrum analysis

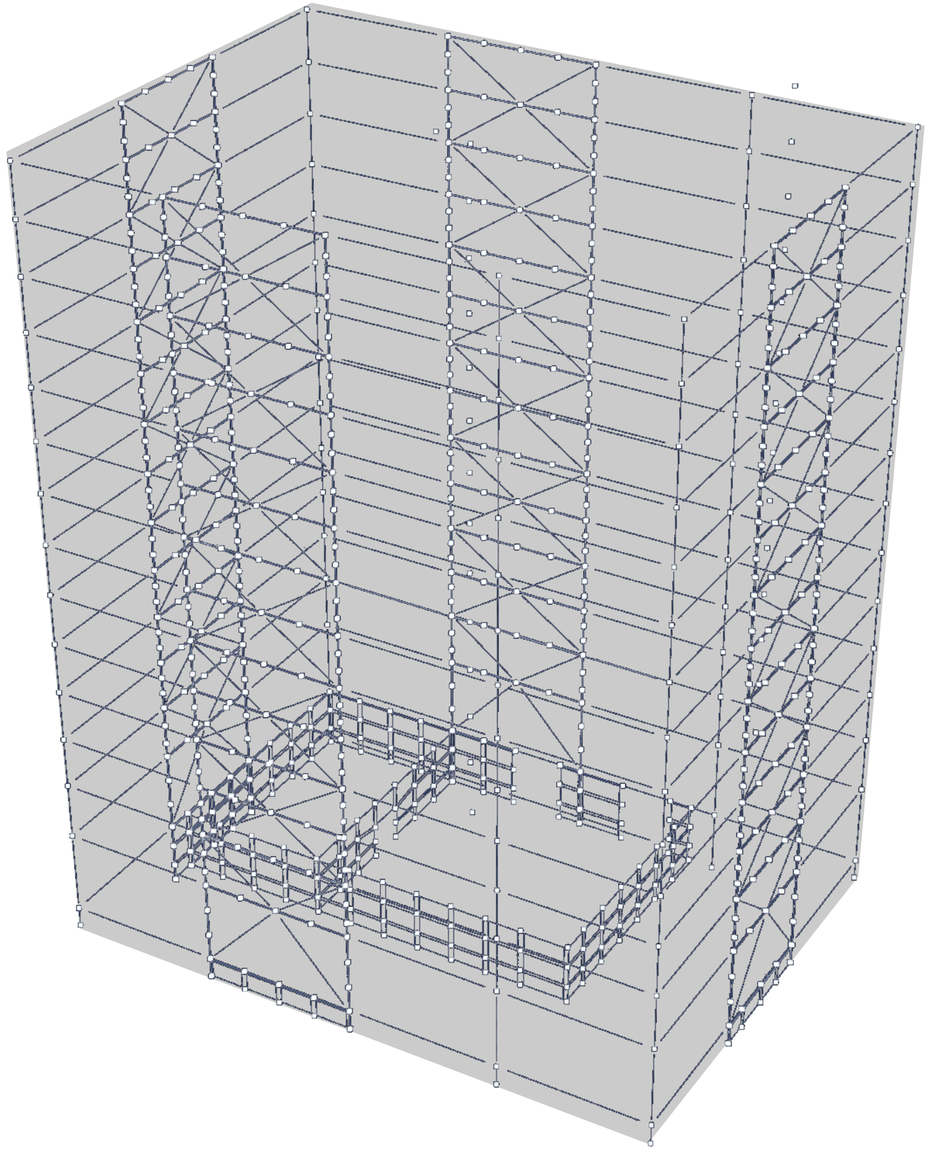
- **475-yr Eq.**
- **R = 8 (Moment Resisting Beam-to-Column Conn.)**

VERIFICATION: (Perform 3D)

Based on Non-Linear Time-History Analysis

- **BSE-1 (475-yr) Eq. = Life Safety**
- **BSE-2 (2475-yr) Eq. = Collapse Prevention**

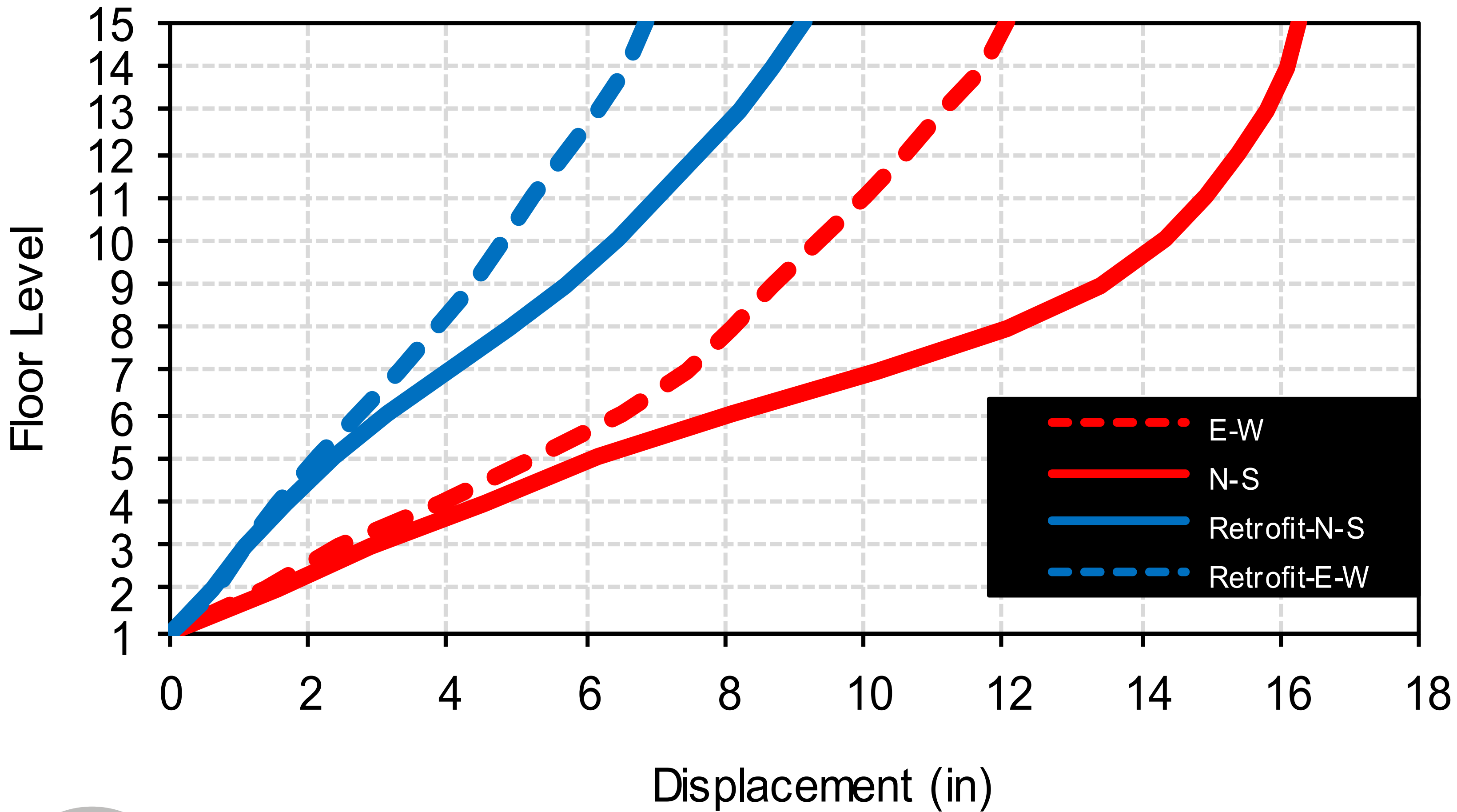
Perform 3D Model



Criteria For Nonlinear Verification Analyses

Components	475-yr Eq.	2475-yr Eq.
Buckling Restrained Braces		
Axial Strain (From Tests)	2.12% (Type B1) 3.04% (Type B2-B5)	2.12% (Type B1) 3.04% (Type B2-B5)
Cumulative Plastic Ductility (From Tests)	400 (Type B1) 1260 (Type B2-B5)	400 (Type B1) 1260 (Type B2-B5)
Existing Concrete Beams **Plastic Rotation** (FEMA-356)	**0.01 rad.**	**0.015 rad.**
New Concrete Beams **Plastic Rotation** (FEMA-356)	**0.02 rad.**	**0.025 rad.**

Existing Building Deflection



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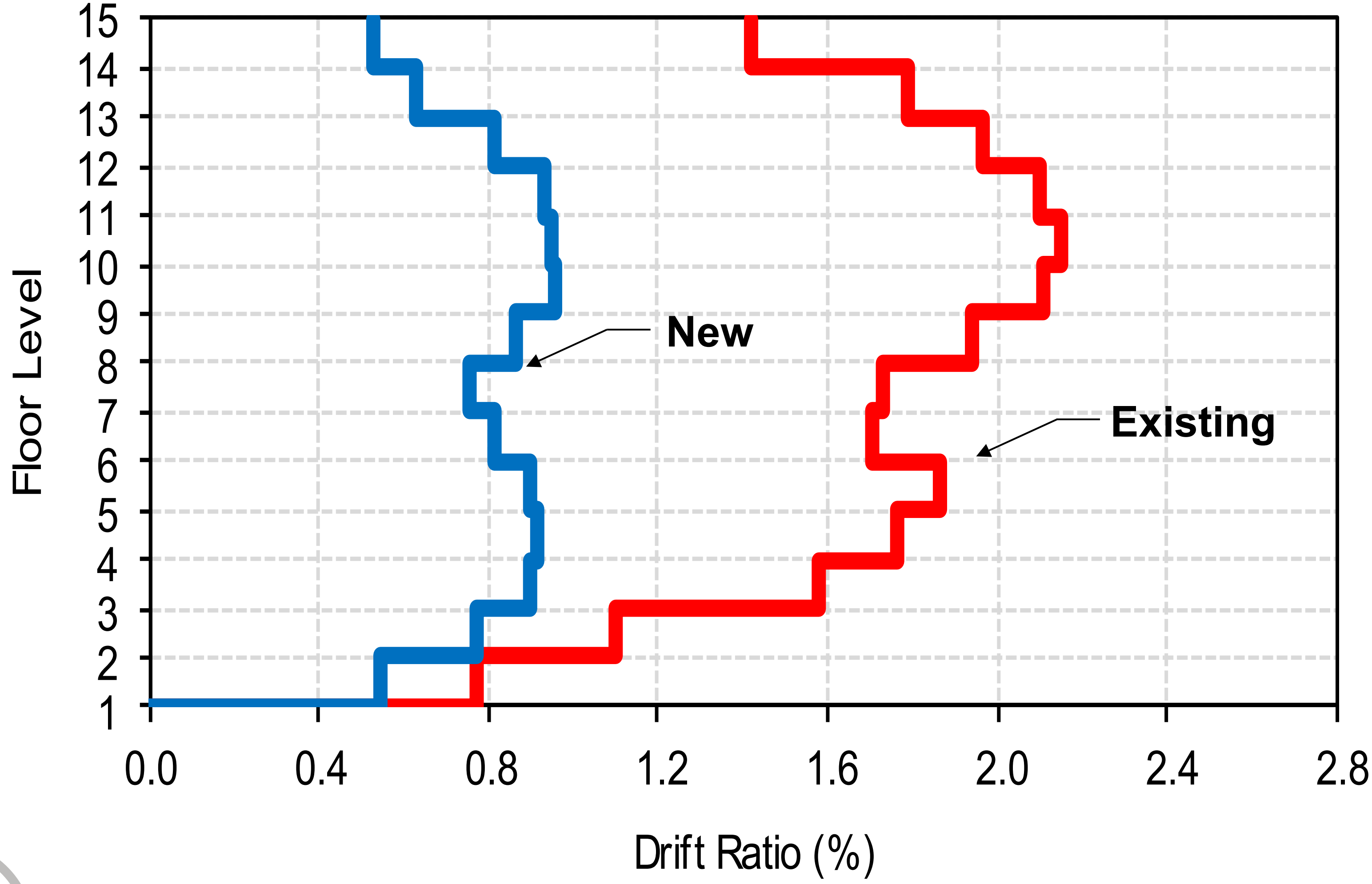
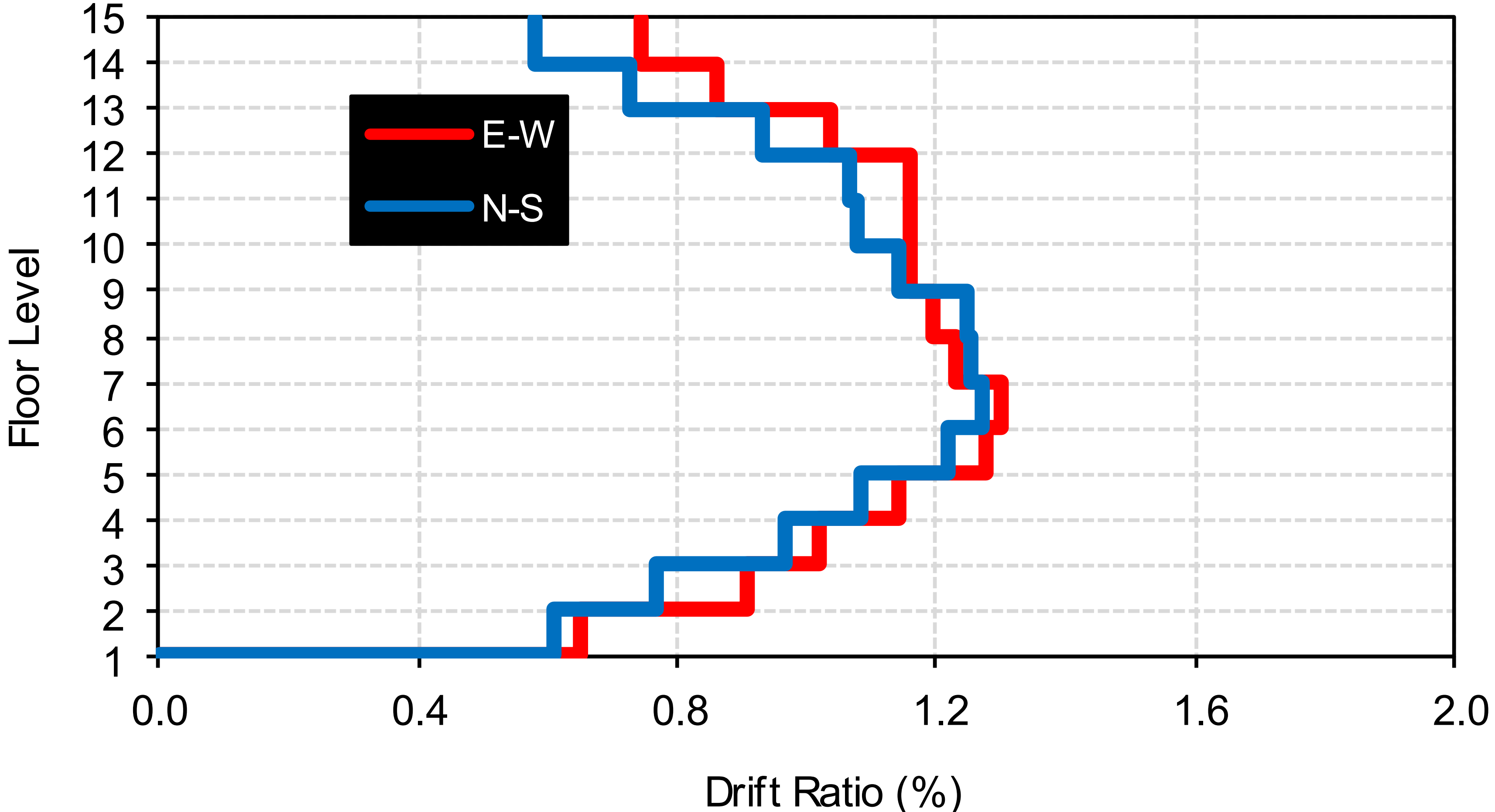
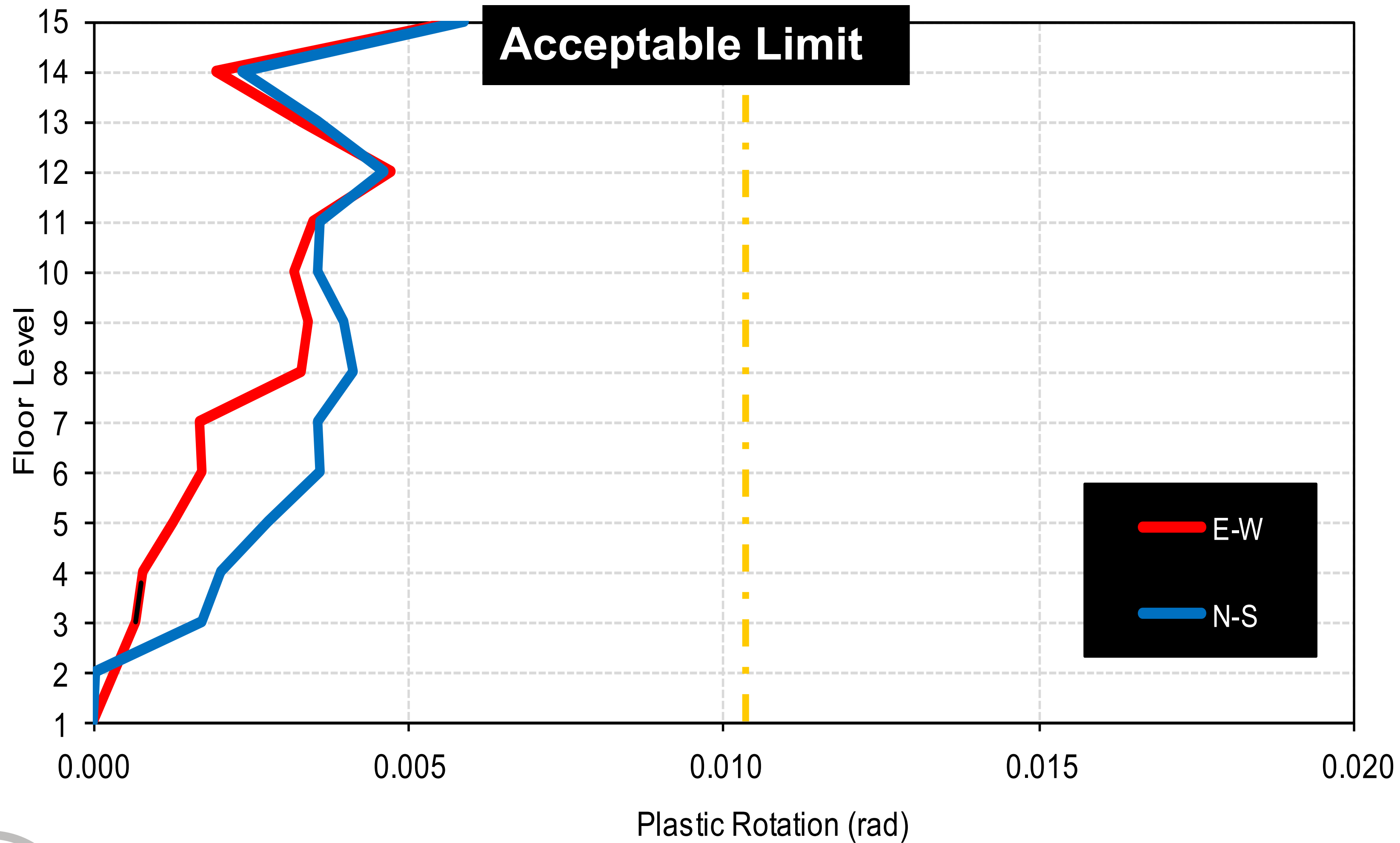
Story Drift (Avg. of 7) – 475 yr EQ



Story Drift (Avg. of 7) – 2475 yr



Existing Beam Plastic Rotation – 475-yr Eq.



Buckling-Restrained Brace Demands

Brace Mark	Brace Nominal Capacity (k)	No. of Braces per Frame	Floor Level	EQIII			EQIV		
				Axial Strain	Ductility	CPD	Axial Strain	Ductility	CPD
B1	230	8	11th-Roof	1.06%	9.7	---	1.45%	13.2	---
B2	380	6	8th-11th	1.31%	12.0	---	1.74%	15.8	---
B3	450	6	5th-8th	1.80%	16.5	129	2.49%	22.8	192
B4	570	6	2nd-5th	1.30%	11.9	---	1.92%	17.6	---
B5	700	2	Grnd-2nd	0.79%	7.2	---	1.55%	14.2	---

Allowable Limits:
Axial Strains: 2-3% CPD: 400 min

Construction Photographs

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CONCLUDING REMARKS

BEFORE

AFTER