Collapse Simulations of Buildings Under Earthquake Conditions

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Abstract

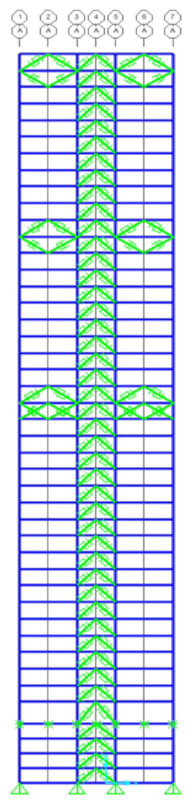
The quality of a high rise building is determined by its lateral strength and resistance to movement. By testing different types of structural supports on the prototype model of a 44 story building (4 basement floors, 40 floors above ground), an observation of the effect of seismic excitations on the structure can be made. The structure can then be optimized to improve its general resilience against seismic activity as well as other load cases that it may encounter.

Loma Prieta Earthquake
Date: January 17, 1989
Duration: 15 seconds
Location: San Francisco
Magnitude: 6.9
Damage Cost: 10 Billion US Dollars
Casualties: More than 67 fatalities, about 3,000 injures

Primary Research Objectives

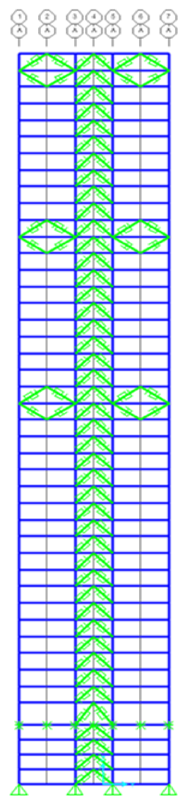
- ❑ Observe structural response
- ❑ Construct building based off structural response
- ❑ Model and optimize structure
- ❑ Create a standard to further build upon

Our Models with Dampers



yz-view of Alpha damper configuration

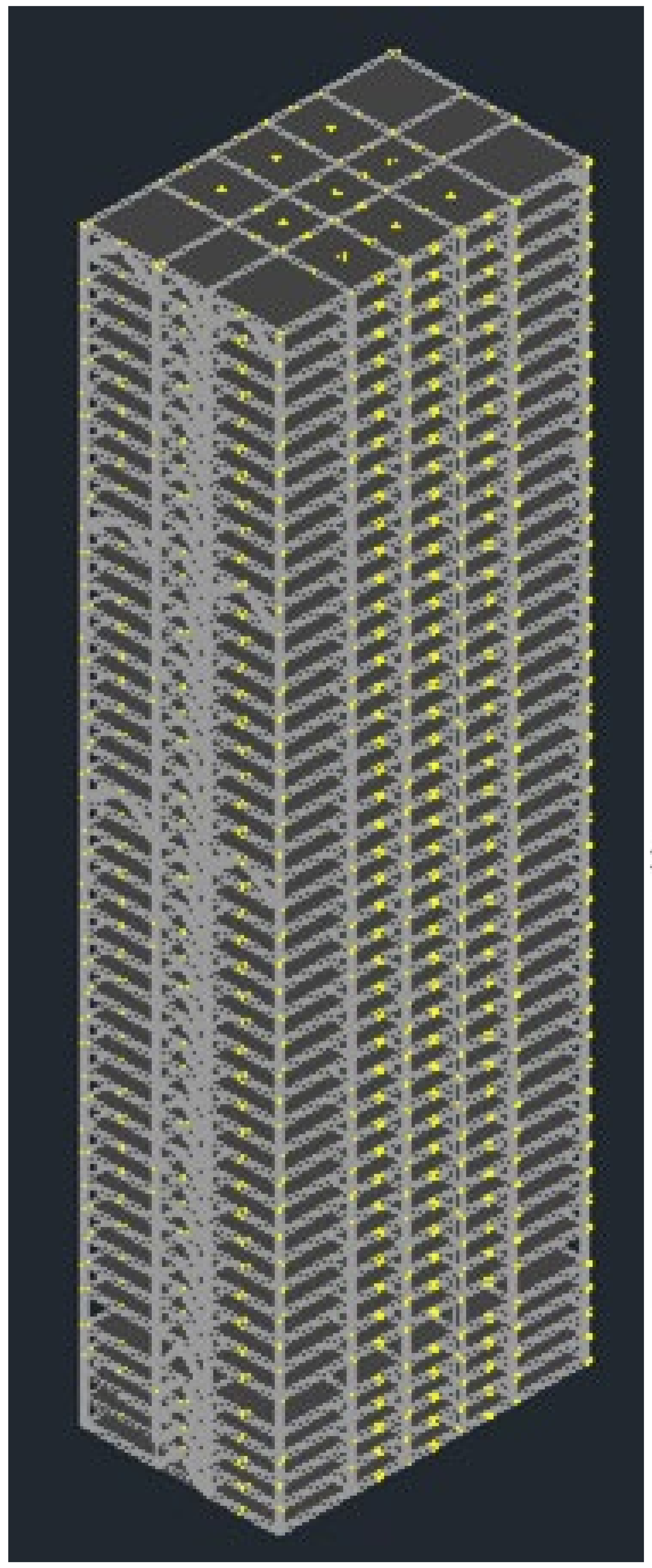
Maximum deflection when subjected to the Loma Prieta Earthquake is 7.57 inches, making it 5.6% more effective than the model without dampers.



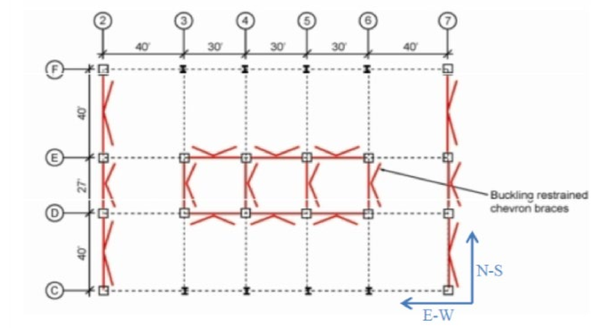
yz-view of Beta damper configuration

Maximum deflection when subjected to the Loma Prieta Earthquake is 7.74 inches, making it 3.4% more effective than the model without dampers.

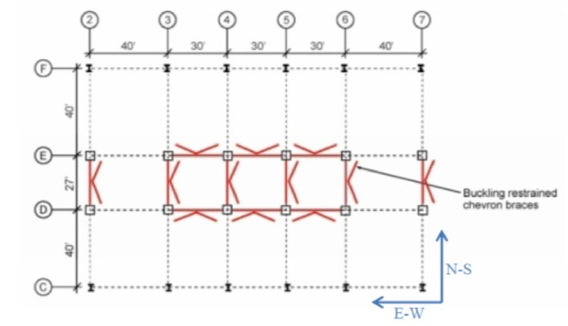
Structural Model



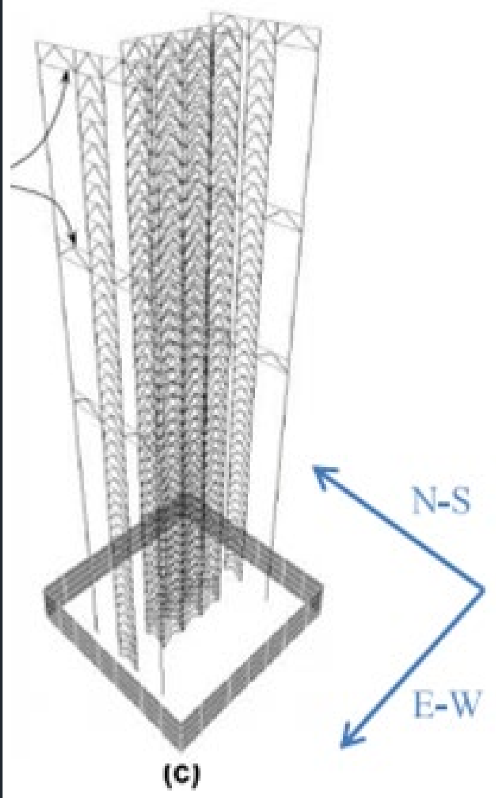
Relevant Figures



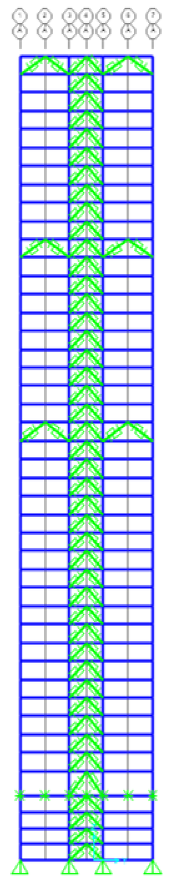
Floor plan for 20th, 30th and 40th floors



Floor plan for all other floors



Building Skeleton



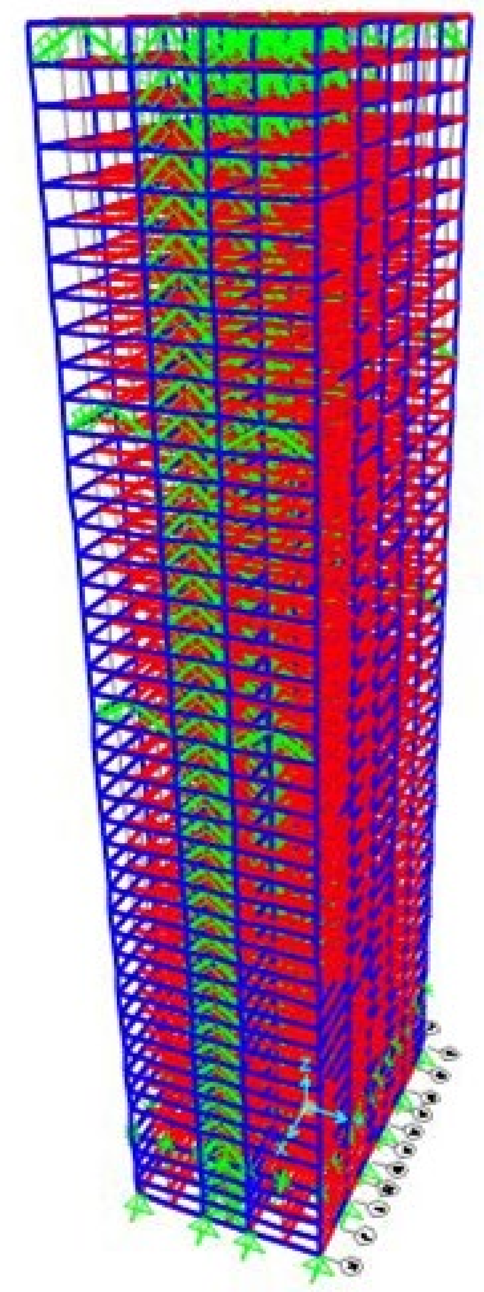
yz-view without dampers

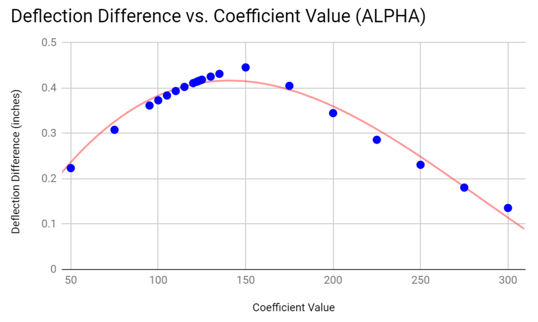
Max Deflection when subjected to Loma Prieta Earthquake:
8.02 inches

Analysis of Structure Under Wind Loads

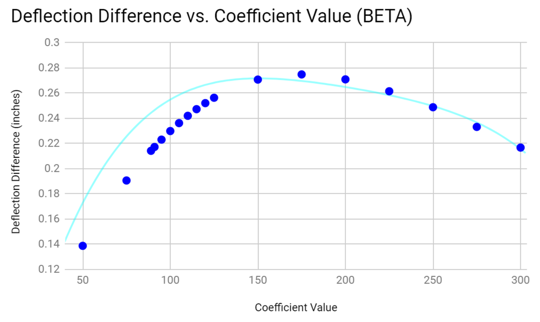
LOAD CASE:	NO BRBs U2 max (in):	NO BRBs U2 min (in):	LINKS U2 max (in):	LINKS U2 min (in):	HINGES U2 max (in):	HINGES U2 min (in):
Wind	9.42E-07	-1.02E-03	9.42E-07	-1.02E-03	3.52E-10	-2.58E-10
Wind-2	79.48	-0.14	79.48	-0.14	12.87	0.00
Wind-3	0.05	-0.06	0.05	-0.06	0.83	-0.83
Wind-4	0.05	-0.06	0.05	-0.06	0.83	-0.83
Wind-5	59.75	-0.10	59.75	-0.10	11.74	0.00
Wind-6	59.74	-0.10	59.74	-0.10	11.73	0.00
Wind-7	0.10	-59.61	0.10	-59.61	0.00	-9.65
Wind-8	59.61	-0.10	59.61	-0.10	9.65	0.00
Wind-9	0.08	-44.89	0.08	-44.89	0.00	-9.42
Wind-10	0.08	-44.89	0.08	-44.89	0.00	-9.44
Wind-11	44.89	-0.08	44.89	-0.08	9.44	0.00
Wind-12	44.89	-0.08	44.89	-0.08	9.42	0.00

Results / Relevant Equations

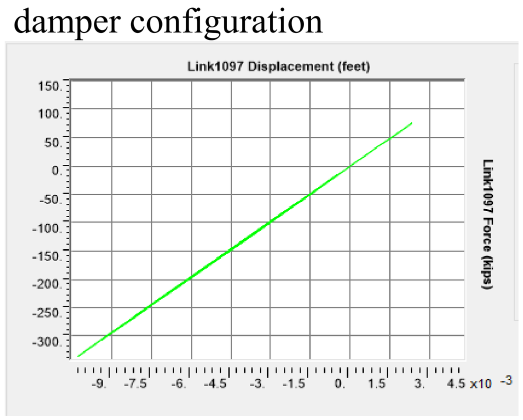




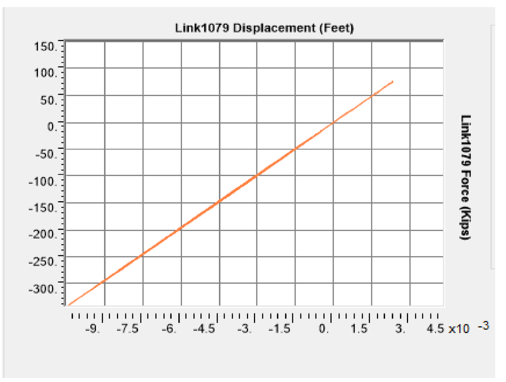
Displacement difference vs. Optimal Coefficient Value analysis of Alpha damper configuration



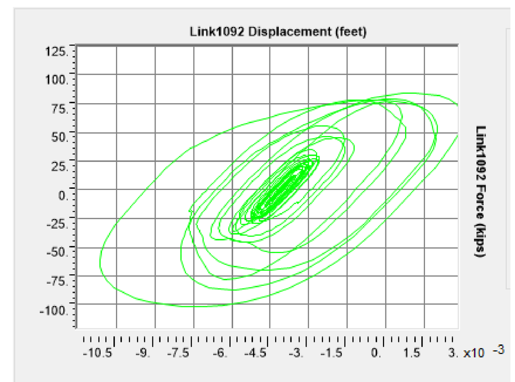
Displacement difference vs. Optimal Coefficient Value analysis of Beta damper configuration



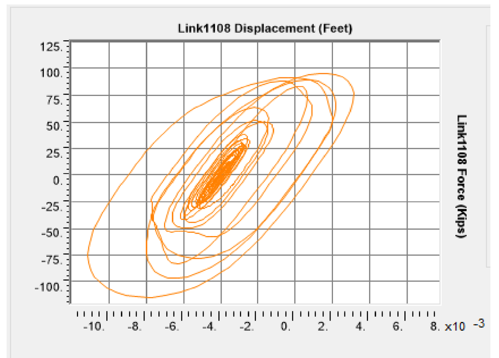
Force vs. Displacement analysis of BRB for Alpha Configuration



Force vs. Displacement analysis of BRB for Beta Configuration



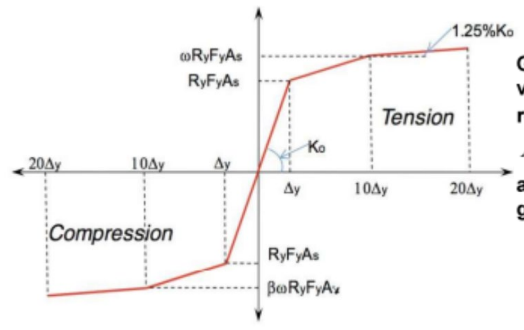
Force vs. Displacement analysis of Alpha Damper Configuration



Force vs. Displacement analysis of Beta Damper Configuration

Note: Above Force vs. Displacement Analysis was computed using Loma Prieta Earthquake

Backbone Curve



General backbone curve for the nonlinear BRB element. The vertical axis represents force and the horizontal axis represents deformation. A_s = area of yielding steel core, K_o = A_sE/L, E = 29,000ksi, F_y =38ksi, R_y = 1.1, ω = 1.25, β = 1.1, and L =70% of the brace length (using center-line to center-line geometry). Image courtesy of Dutta and Hamburger [2010].

Backbone Curve for BRB equations

$$h = 10\Delta y * tan(\frac{1.25}{100} * k_0) \qquad \Delta y = \frac{L\sigma}{E}$$

$$k_0 = \frac{A_s E}{L} \qquad D = C + \frac{h}{F_y A_s}$$

Conclusion

- ❑ Analyzed the behavior of 44-story building with outrigger system, buckling restrained braces and dampers.
- ❑ Tested out different damper configurations and coefficient of stiffness to find the optimized structure
- ❑ Carried out hysteresis analysis to study the structural integrity
- ❑ Applied wind load tests to further analyse the behavior of BRBs and dampers on a cyclical basis

Acknowledgments

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