

Simpson Gumpertz & Heger Inc. Consulting Engineers

Building Engineering ■ Infrastructure and Special Structures ■ Construction Engineering

Importance of Acceleration Related Issues in the Selection of Structural Systems

Property Damage Risk

- Structural cost +/- 20% of the building cost
- Contents, Architectural, MEP etc +/- 80% of the building cost
- Earthquakes cause greater dollar damage to contents, mechanical and electrical equipment and nonstructural elements

Earthquake Damage

Caused by High Floor Accelerations

- Ceiling & Lights
- Building Equipment
- Elevators
- Contents

Caused by Large Interstory Drift

- Structural Frame
- Piping & Ductwork
- Facade & Windows
- Partitions

Acceleration Related Damage – Kobe Video



Earthquake Damage

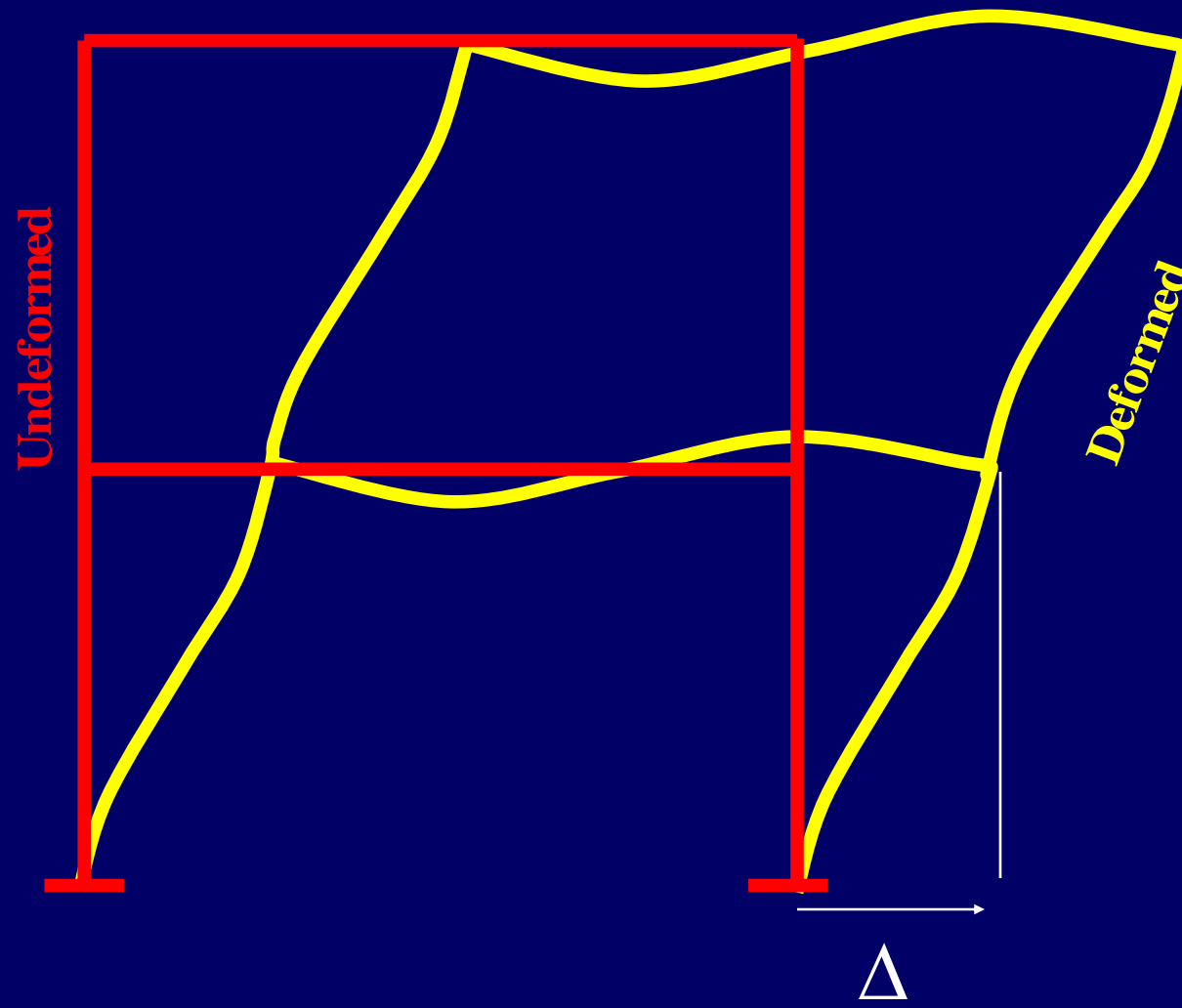
Caused by High Floor Accelerations

- Ceiling & Lights
- Building Equipment
- Elevators
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Caused by Large Interstory Drift

- Structural Frame
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- Facade & Windows
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FRAME DEFORMATION and DRIFT UNDER LATERAL LOADS



Framing Schemes Included in Comparative Study

- Moment Frame
- Buckling Restrained Braced Frame
- Viscously Damped Frame
- Base Isolated Braced Frames

Project Overview

- 3, 9 and 20 story SAC buildings designed using 1997 UBC
- Buckling restrained braced frames had steel braces each with 45 Ksi yield level.
- In the 3 story building R-Factors of 7 and 3.5 were used to assess the impact of better drift performance.
- Viscously damped moment frames were designed using 75% of the base shear and the dampers were designed to meet the 2% drift criteria.
- In the 3 story building the minimum damper force was doubled to assess higher levels of performance.

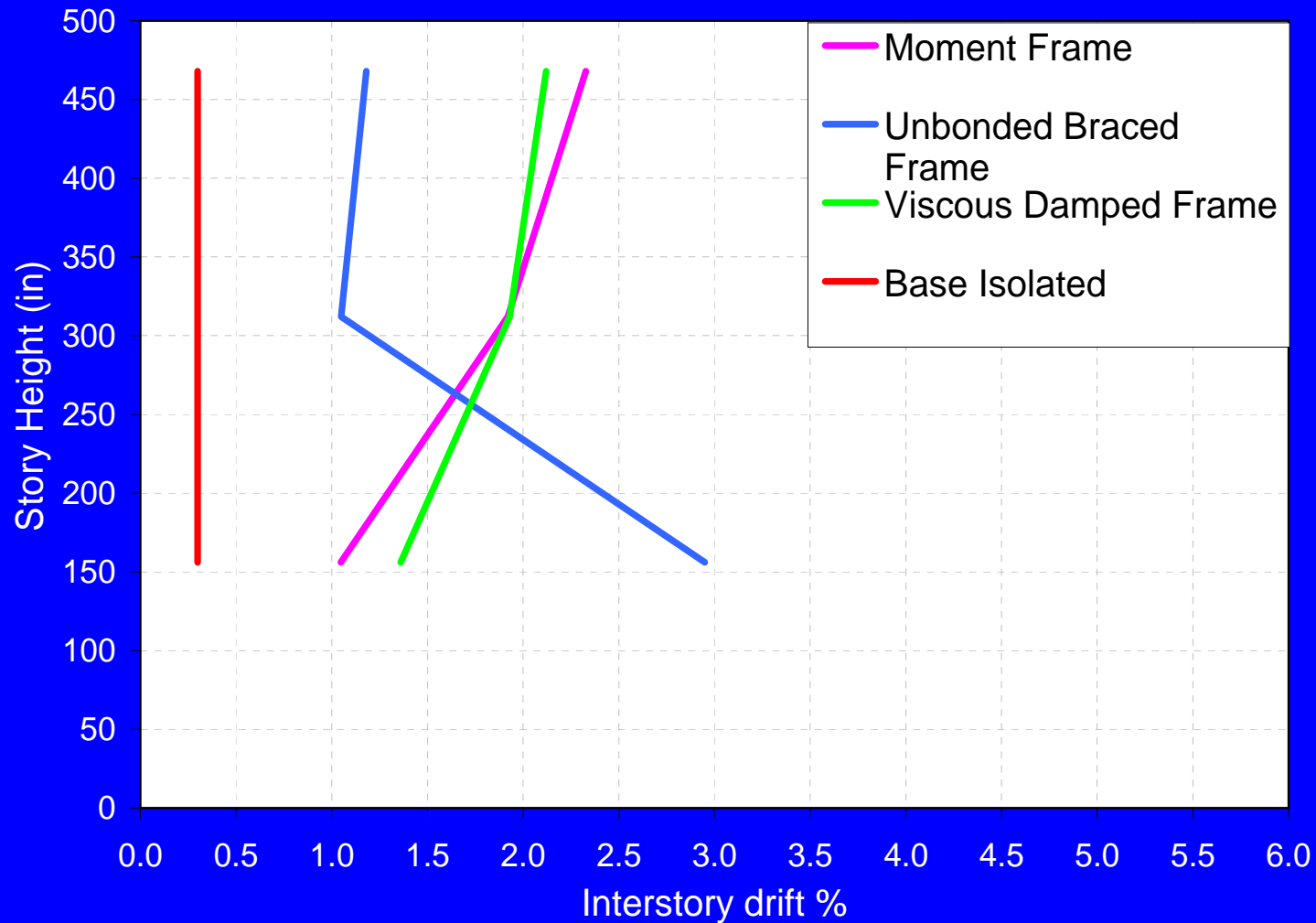
Earthquakes

- The design earthquakes were:
 - 50% in 50 year – moderate event
 - 10% in 50 year – design event
 - 2% in 50 year – maximum credible event
 - Near fault events – within 10 miles of a fault
- Key results from 5 time histories for each event are averaged.
- We will focus on the results of the 50% and 10% in 50 year events.
- All seismic resisting elements were modeled with their non-linear properties using RAM-Perform

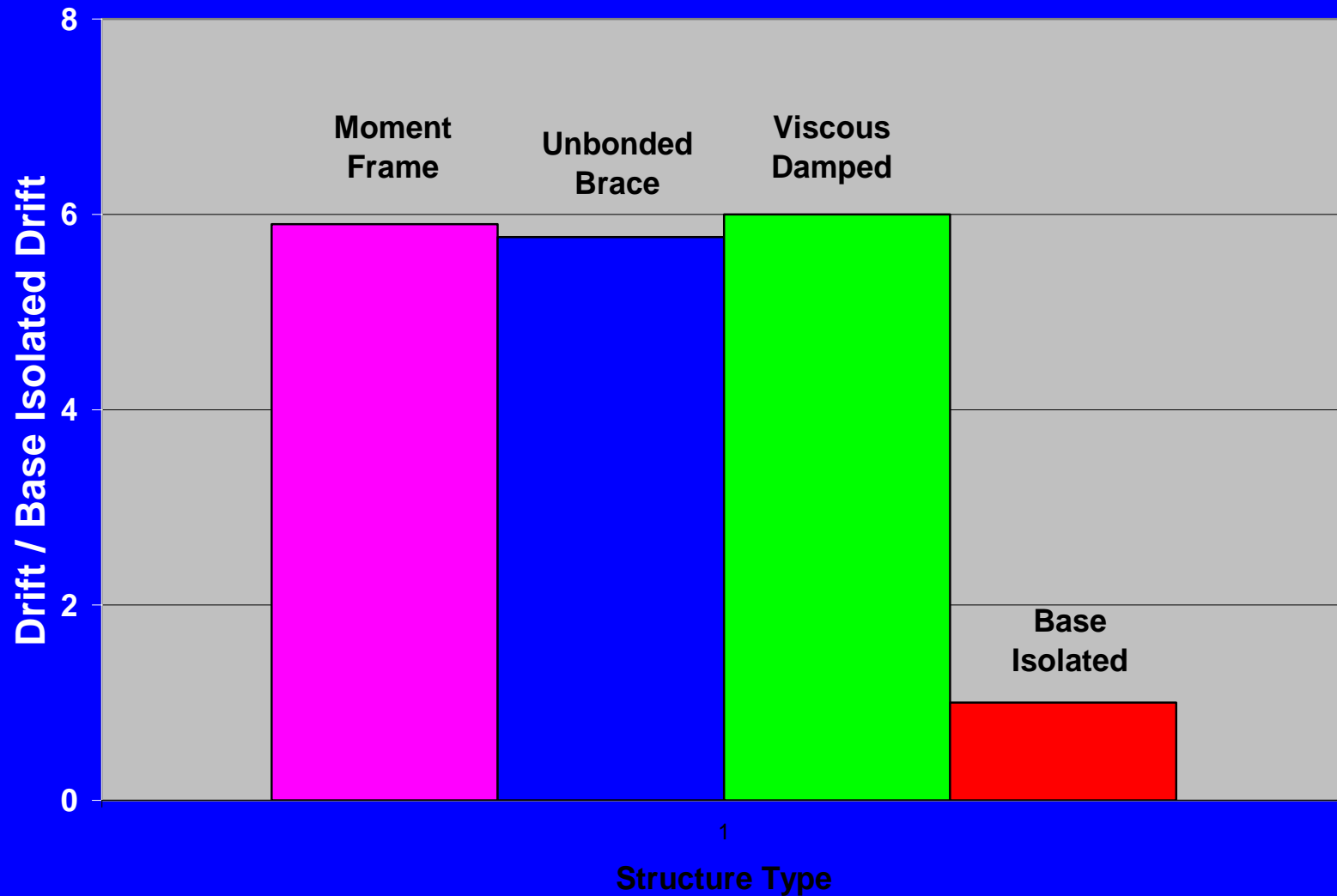
1st Key Performance Parameter

- Inter-story Drift – key code design parameter
 - Impacts structural frame, building façade, piping and ductwork, partitions
 - 2% drift with 13 ft. story height is 3 inches of inter-story displacement

% Average Interstory Drift 3 Story - 10% in 50yr Event

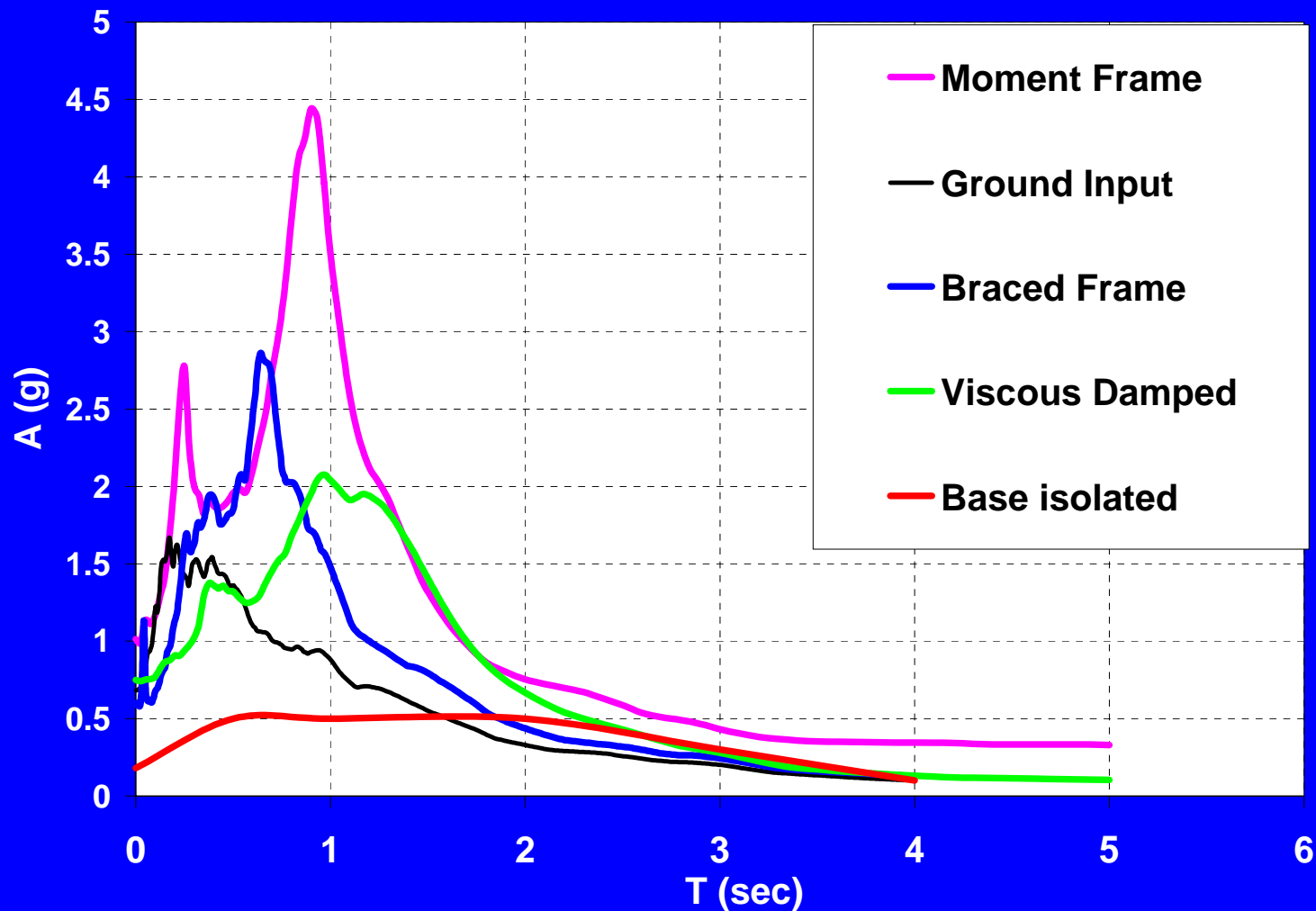


Normalized Mean Interstory Drift 3 Story - Design E/Q (10% in 50 Year Event)

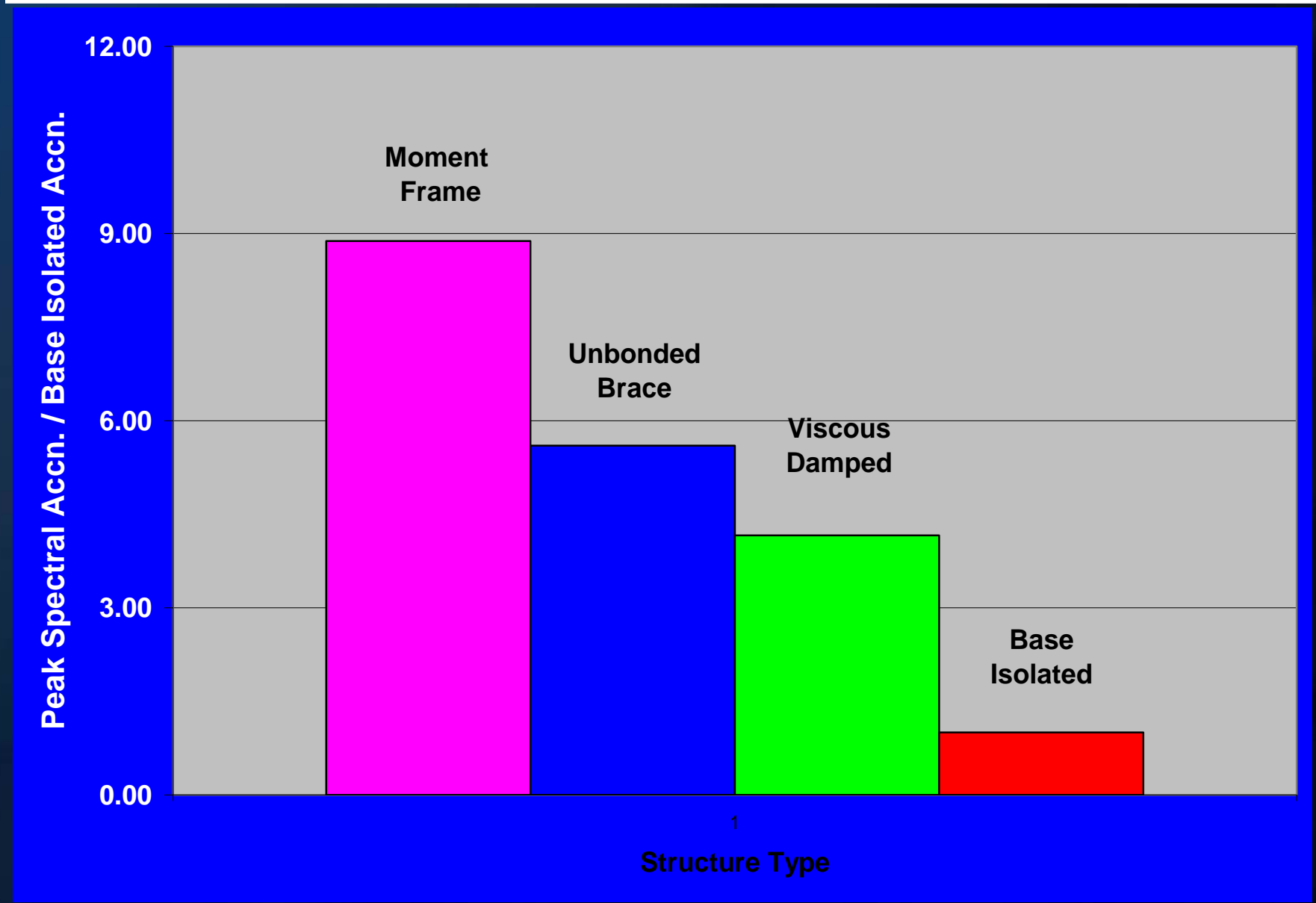


Peak of the Floor Response Spectra Damage to Flexible Contents and MEP

Average Floor Spectra for 10% in 50yr Event
3 Story - 3rd Floor



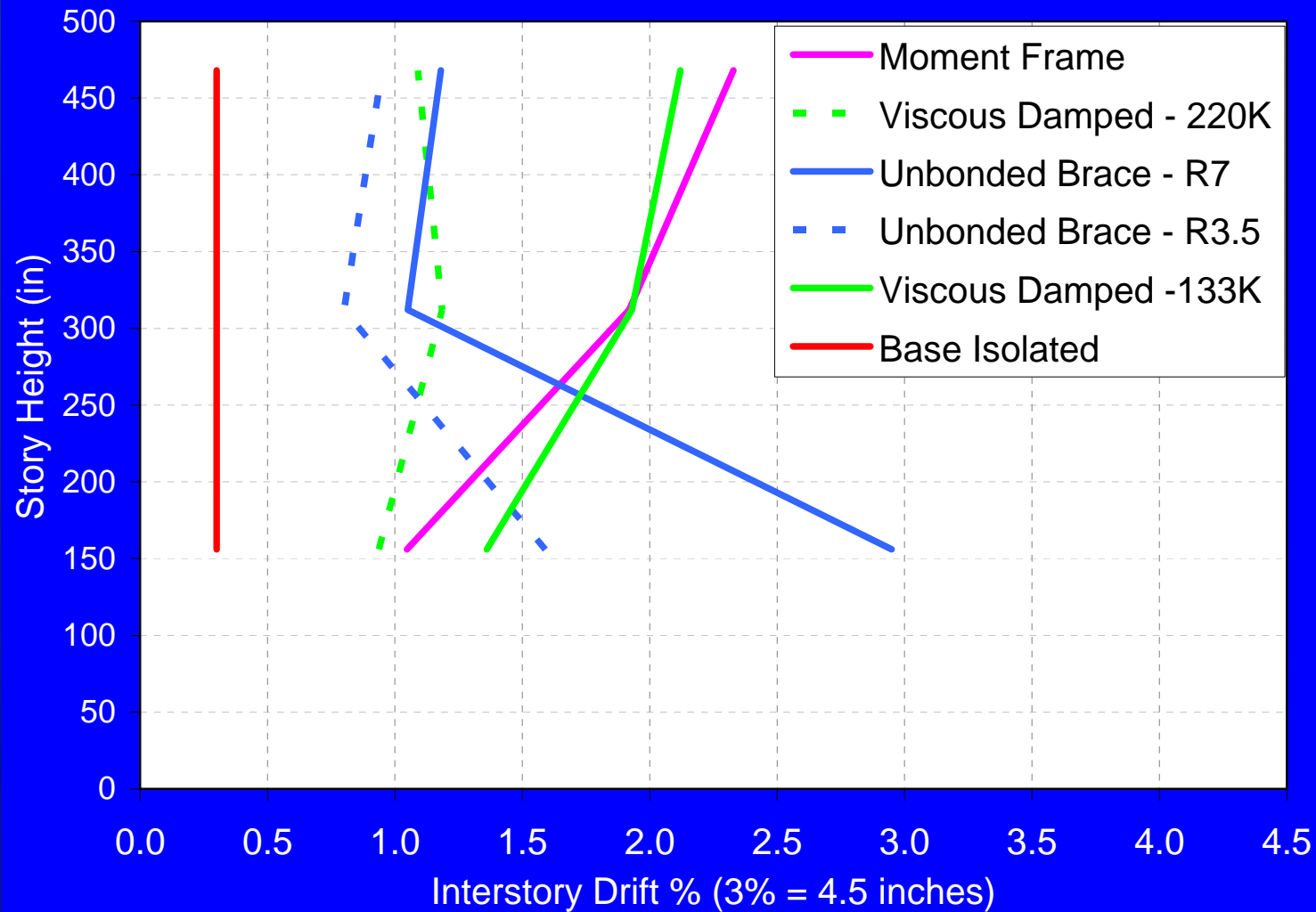
Normalized Peak Floor Spectral Acceleration 3 Story - Design E/Q (10% in 50 Year Event)



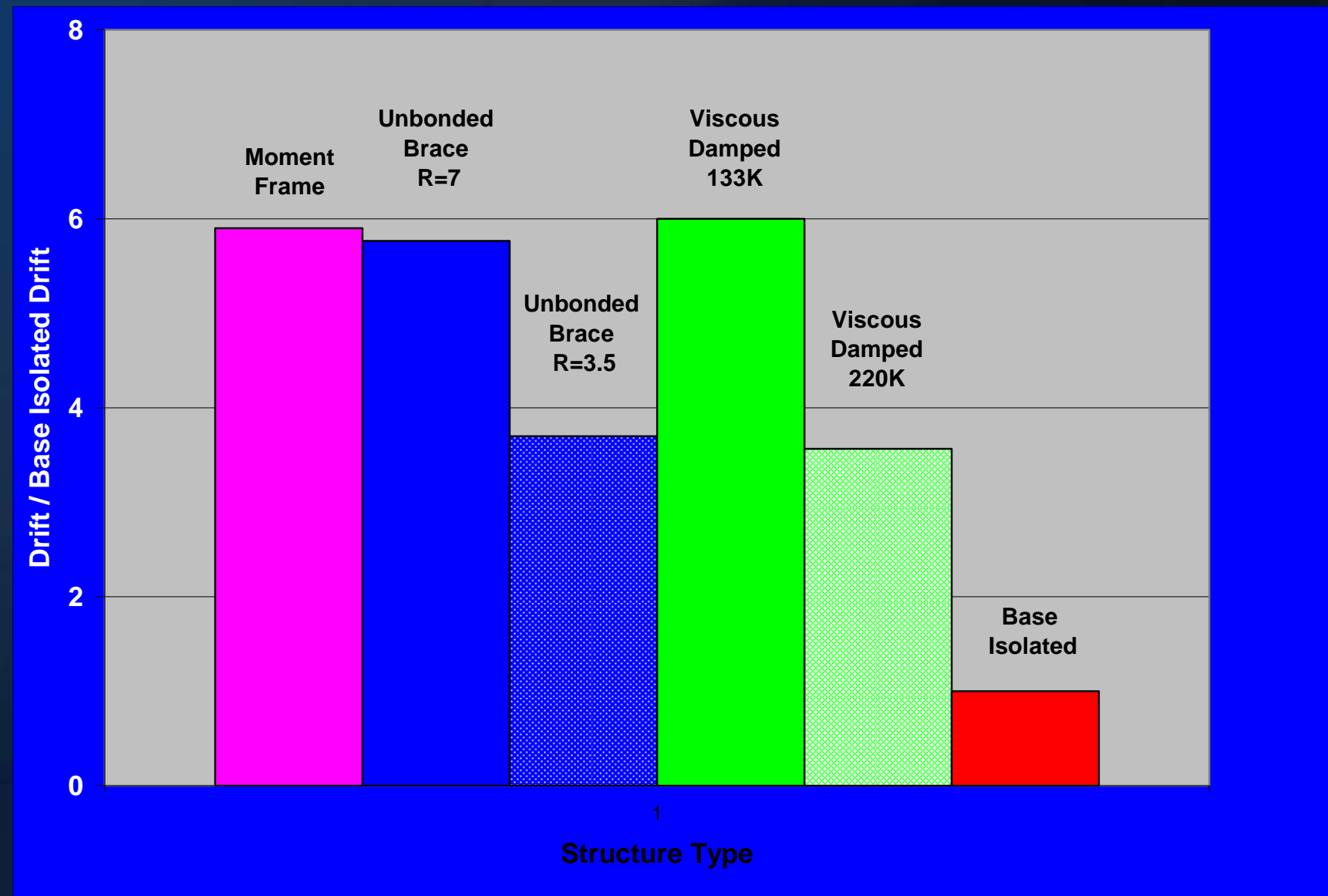
Comparison of Improved Drift Performance Hospital Design Requirements

- Unbonded braced frame – reduce the R-Factor from 7 to 3.5
- From a design perspective this is similar to using an $N_v = 1.6$ and $I = 1.25$ in 97 UBC or an increase of 1.33 in the S_s and S_1 values and an $I = 1.5$ in the IBC. This effectively reduces the design interstory drifts.
- Viscously damped frame – double damper force from 133 K to 220 K

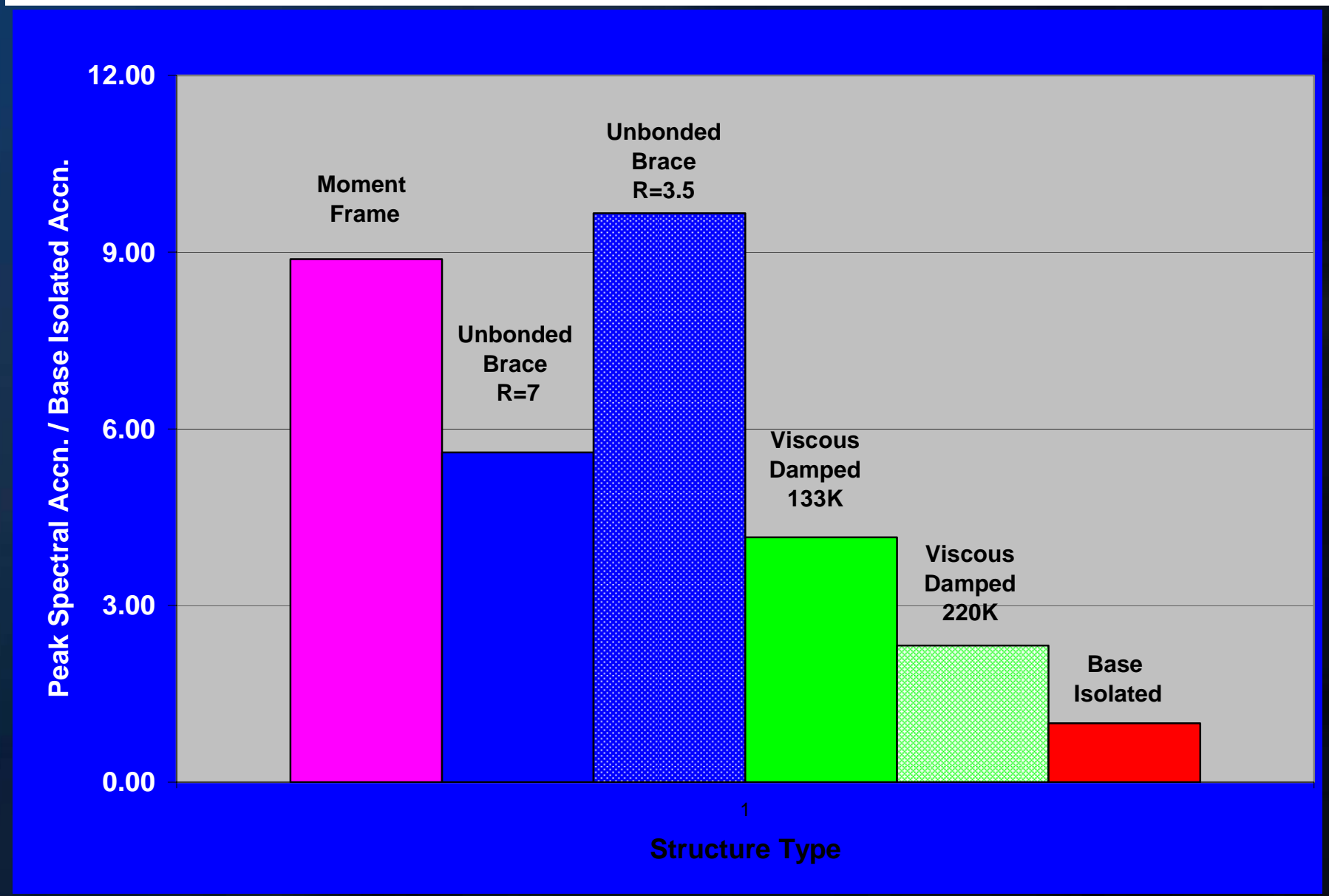
% Average Interstory Drift 3 Story - 10% in 50yr Event



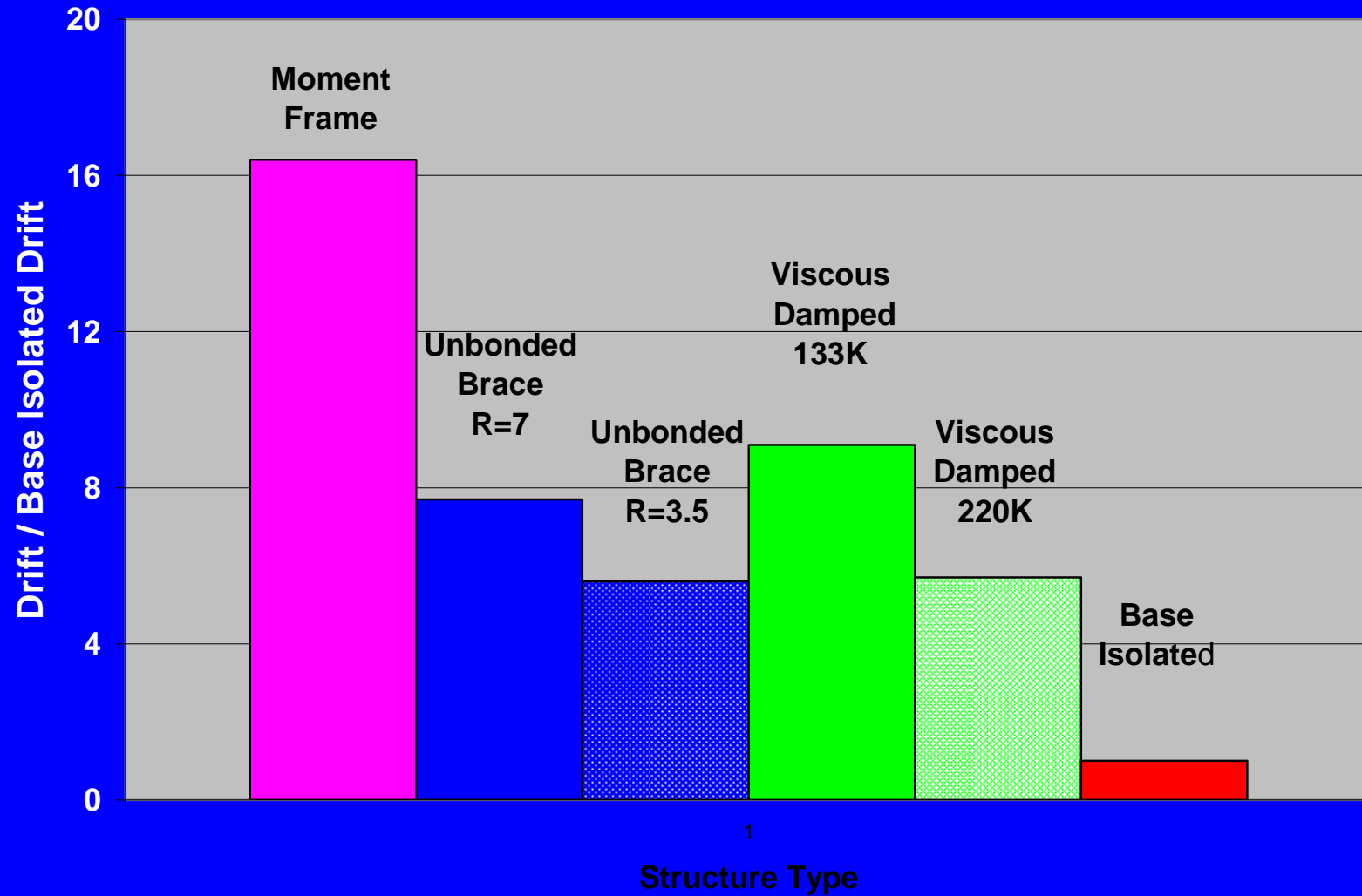
Normalized Mean Interstory Drift 3 Story - 10% in 50 Year Event



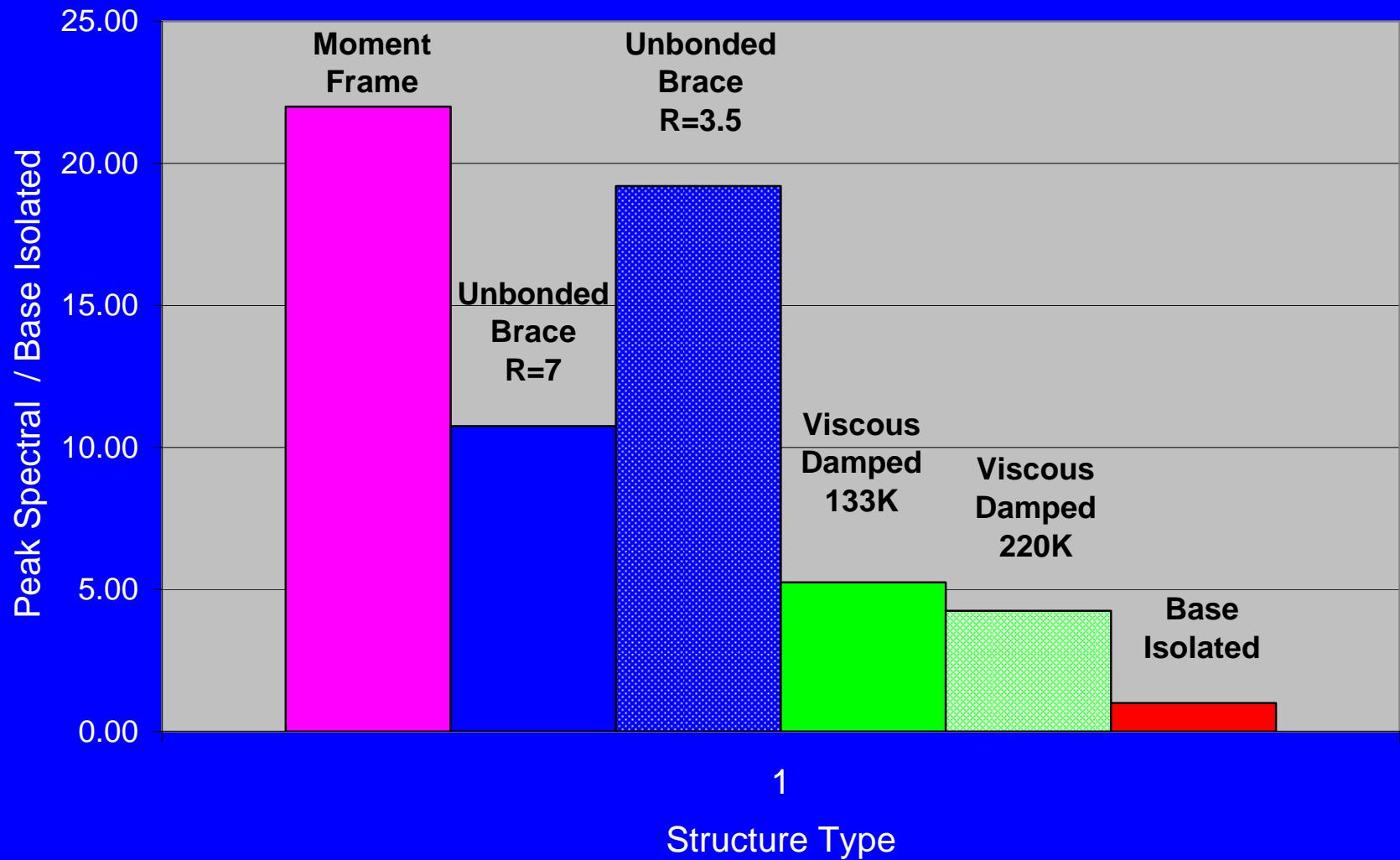
Normalized Peak of the Floor Response Spectra 3 Story - 10% in 50 Year Event



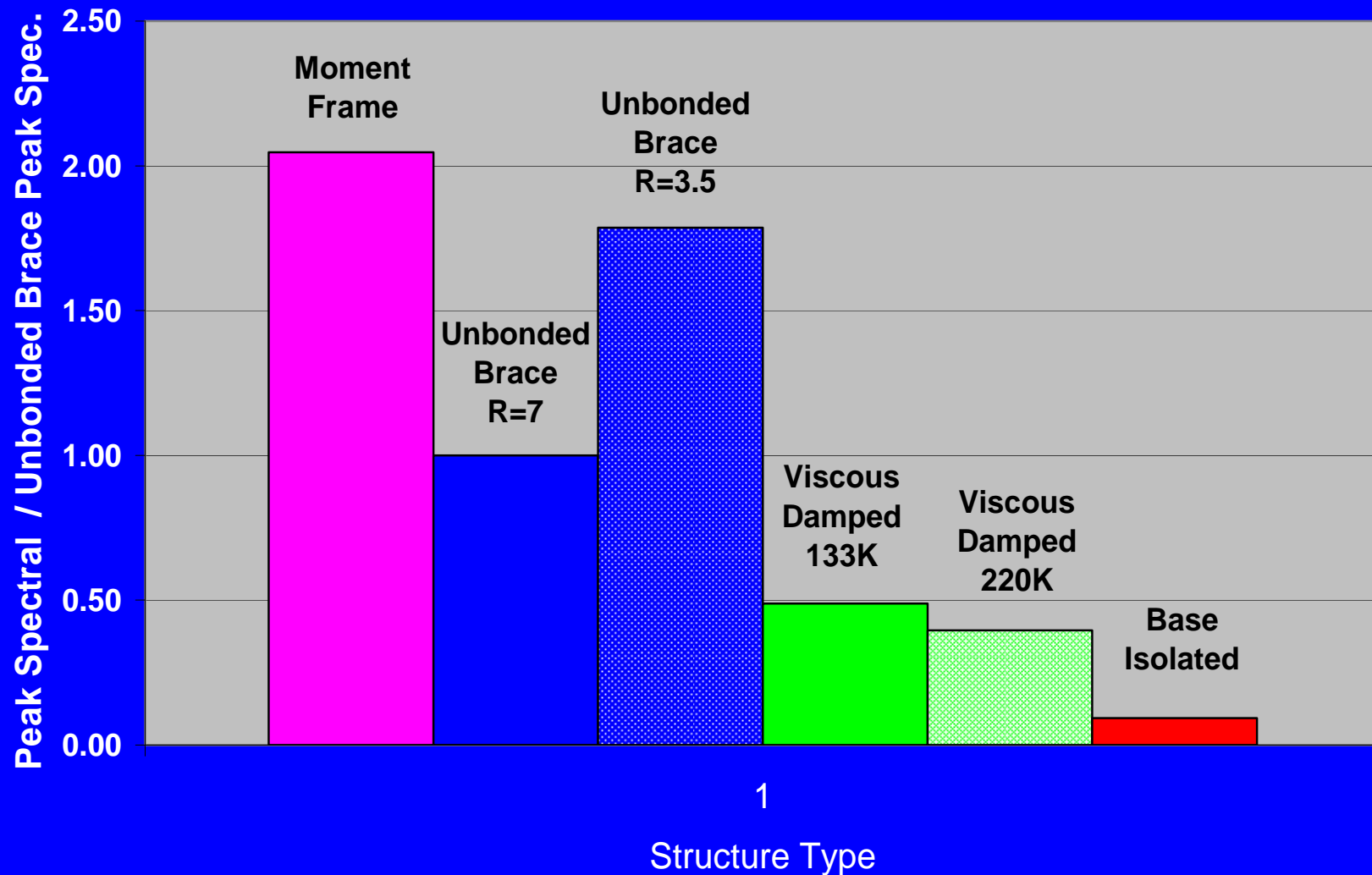
Normalized Mean Interstory Drift 3 Story - Moderate E/Q (50% in 50 Year Event)



Normalized Peak of the Floor Response Spectra 3 Story - Moderate E/Q (50% in 50 Year Event)



Normalized Peak of the Floor Response Spectra 3 Story - Moderate E/Q (50% in 50 Year Event)



Relative Costs – 3 Story Hospital

Code Design	Framing Cost \$ / sq. ft.	Total Cost \$ / sq. ft.	Increase Cost Over MF
Moment Frame	\$27.10	\$250.00	Baseline
Viscous Damped	\$27.70	\$250.60	0.2%
Buckling Restrained R=7	\$26.00	\$248.90	- 0.44%
Base Isolated	\$39.00	\$261.90	4.7%
Concentric Braced	\$23.40	\$246.30	- 1.5%
Improved Drift Performance			
Viscous damped	\$28.50	\$251.40	0.56%
Buckling Restrained R=3.5	\$26.80	\$249.70	- 0.1%

Note: Base isolation cost is \$39 / sq. ft. of plan area or an additional \$13 / sq. ft for a concentric braced frame.

Relative Costs – 9 Story Hospital

Code Design	Framing Cost \$ / sq. ft.	Total Cost \$ / sq. ft.	Increase Cost Over CBF
Moment Frame	\$27.40	\$250.00	Baseline
Viscous Damped	\$28.20	\$250.80	0.3%
Buckling Restrained	\$27.10	\$249.30	- 0.3%
Base Isolated	\$27.80	\$250.40	0.2%
Concentric Braced	\$23.40	\$246.00	- 1.6%

Note: Base isolation cost is \$39 / sq. ft. of plan area or an additional \$4.50 / sq. ft. for a concentric braced frame.

Relative Performance of Different Systems

- Base isolation provides significantly lower inter-story drift and floor accelerations – operational performance
- If a braced frame is being considered then a viscous damped frame performs significantly better than a buckling restrained brace in terms of floor accelerations

Relative Total Costs of Different Systems

- For the 9 story hospital and office building the costs of all design options are considered “equal”.
- For the 3 story hospital the framing schemes are all within 1% and the isolated building is an additional 4.7%.
- The taller the building the less the premium for base isolation.

Thank You