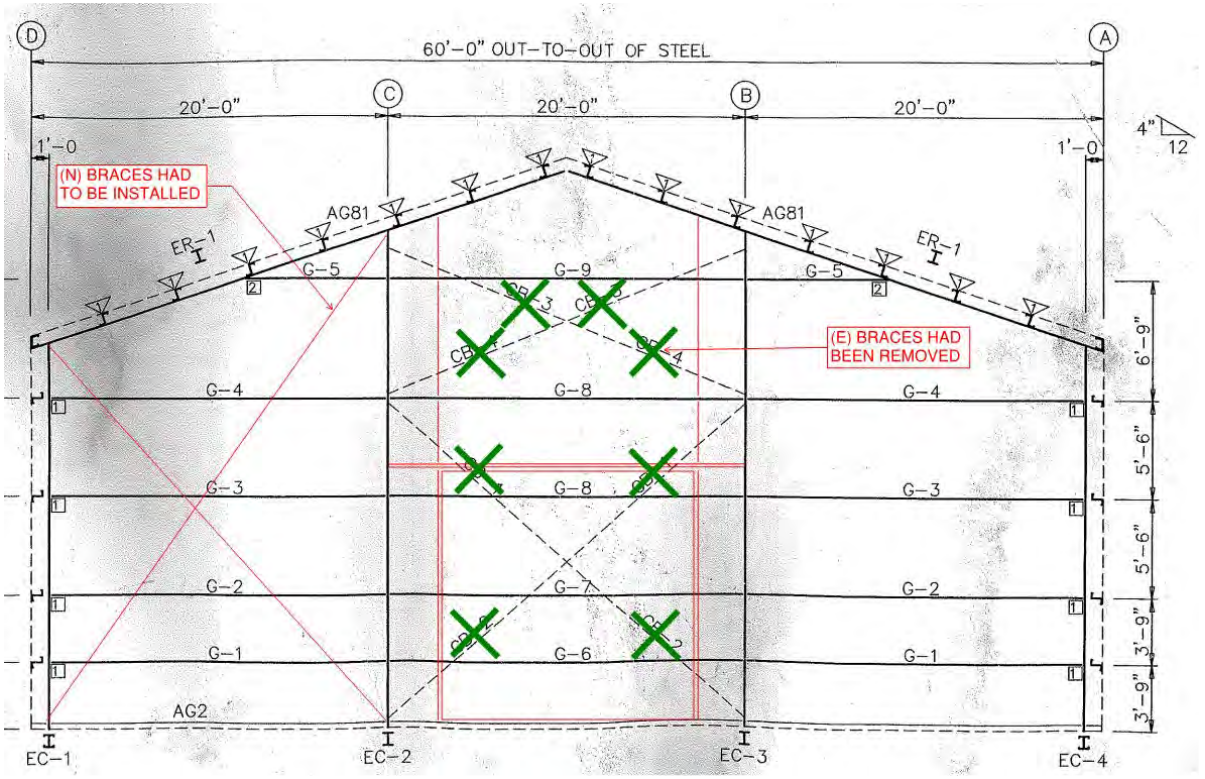
Perpetual Modifications



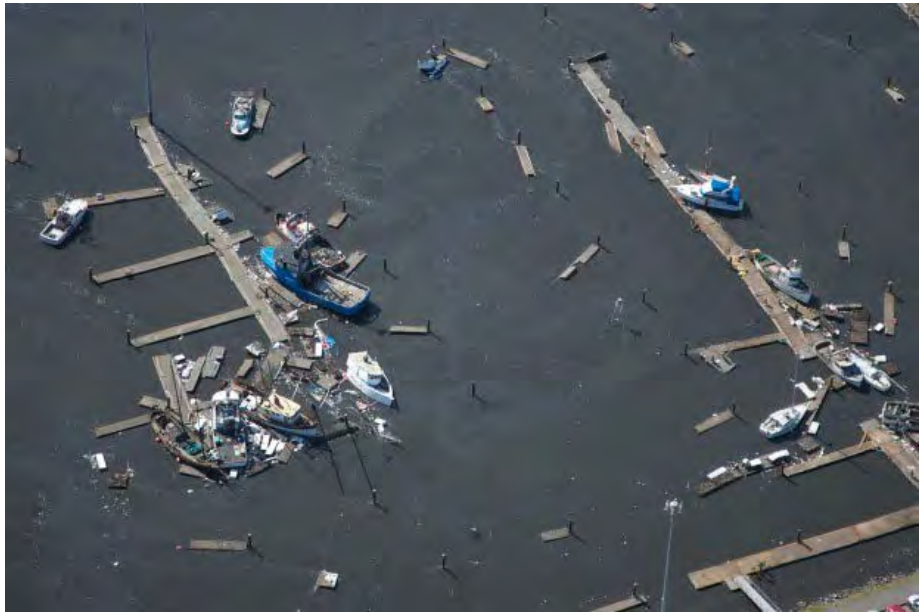
Liquefaction & Ground Displacement

Roadway damage in 2018 Anchorage Earthquake

Compression buckling in railway in 2010 Canterbury, NZ Earthquake

Tsunamis

Tsunami damage in Kodiak, AK in 1964 Great Alaskan Earthquake



Tsunami damage in Crescent City, CA from the 2011 Tokohu Earthquake in Japan

Earthquake Damage Summary

- Building structures without irregularities or deficiencies typically perform well in earthquake events
- 80-90% of all earthquake losses can be attributed to non-structural elements
- More attention needs to paid to these non-structural elements in the future to minimize downtime and losses

Ceiling damage in the 2011 Christchurch Earthquake in New Zealand

How to Prepare for Future Earthquakes

- Personal Preparedness
- Business Preparedness
- Evaluate Seismic Risk
- Performance Objectives
- Seismic Retrofits

Personal Preparedness

- Earthquake/Tsunami Alerts
- Drop, Cover, Hold On
- Emergency supplies & water for (3) days
- Expect no electricity, internet or phones (texting best communication)
- Stuck doors/windows

Business Preparedness

- Emergency Response Plan
  - Pipe Breaks
  - Hazmat Releases
- Who will survey damage & determine when reoccupancy is safe?
- Plan for potential interruptions
  - Communications
  - Roads/Bridges
  - Rail
  - Ships

Evaluate Seismic Risk

- Determine Seismic Hazard
- Determine Critical Functions/ Processes for Operation
- Determine Cost of Downtime
- Structural Survey / Earthquake Loss Estimation
- Determine Seismic Performance Objective

Earthquake Physical Damage Estimate
(% of replacement cost)
200-year recurrence interval scenario

Building	SEL (Mean Loss)	SUL (or NUVEEN PML) 90th Percentile Loss
Seattle High Rise (2009)	7	11

Earthquake Physical Damage Estimate
(% of replacement cost)
475-year recurrence interval scenario

Building	SEL (Mean Loss)	SUL 90th Percentile Loss
Seattle High Rise (2009)	10	16

Earthquake Physical Damage Estimate
(% of replacement cost)
Maximum Capable Earthquake scenario

Building	SEL (Mean Loss)	SUL 90th Percentile Loss
Seattle High Rise (2009)	15	22

Seismic Performance Objectives

- Prior to 1997
  - Life Safety for 5%/50-yr event “k”
- Current Code
  - Life Safety for 2%/50-yr event “o”
- Future
  - Immediate Occupancy (Functional Recovery) for 2%/50-yr event “n”
  - Approximately 1-3% increased cost for new construction

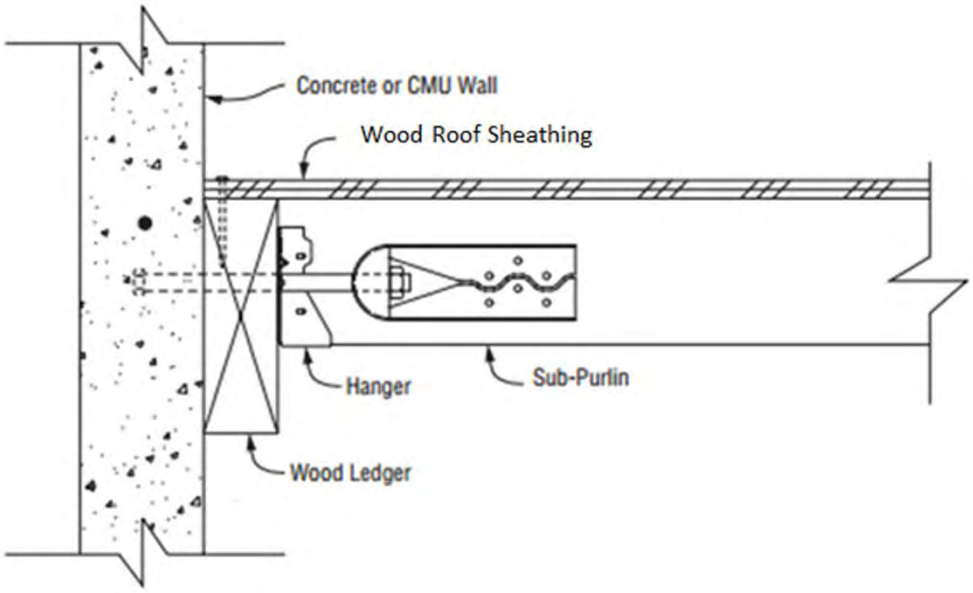
Table C2-2. Performance Objectives

	Target Building Performance Levels			
Seismic Hazard Level	Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-D)
50%/50 years	a	b	c	d
BSE-1E (20%/50 years)	e	f	g	h
BSE-2E (5%/50 years)	i	j	k	l
BSE-2N (ASCE 7 MCE_R)	m	n	o	p

NOTES: Each cell in the above matrix represents a discrete Performance Objective.

Source: ASCE 41-13 Seismic Evaluation and Retrofit of Existing Buildings

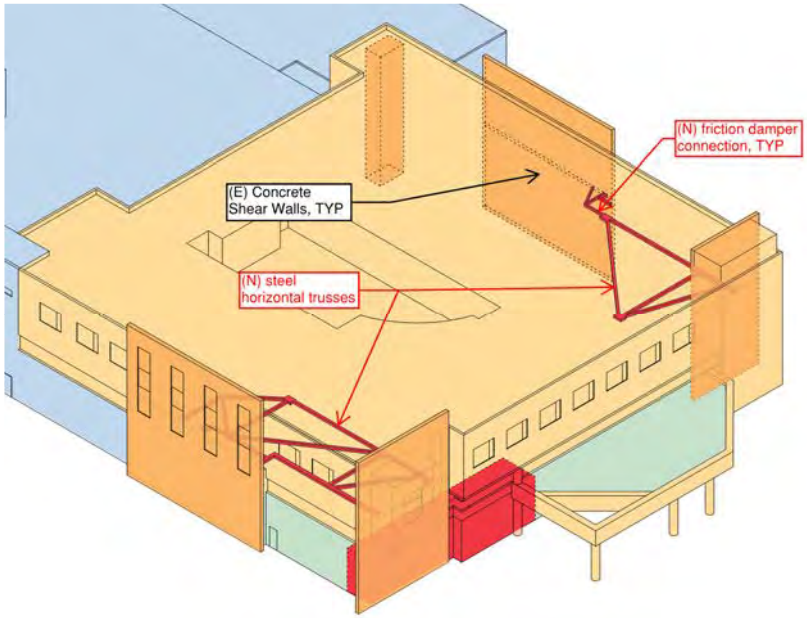
Seismic Retrofits



Wall Out-of-Plane Anchorage

Pipe Seismic Bracing

Seismic Retrofits – Friction Dampers



Seismic Retrofits – Viscous Dampers

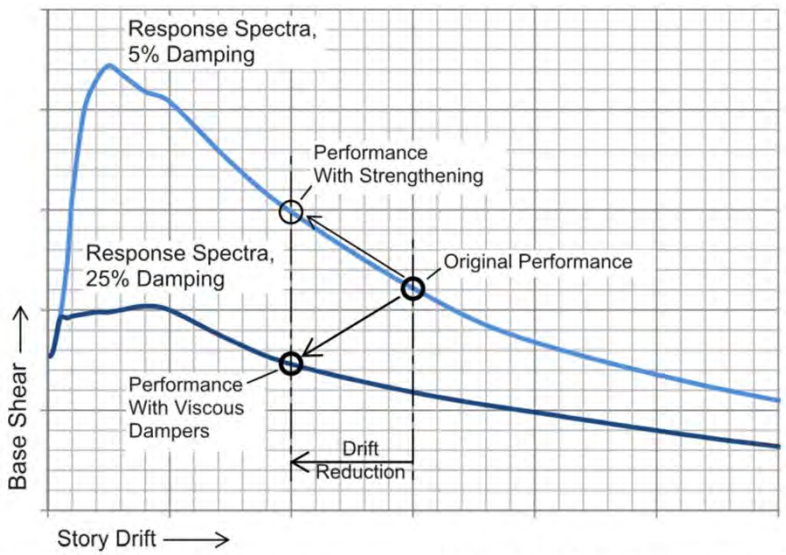
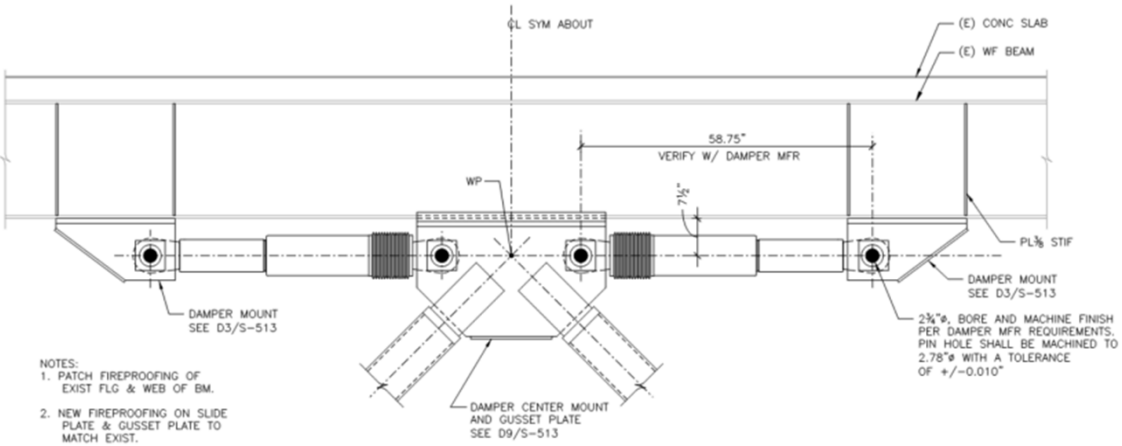
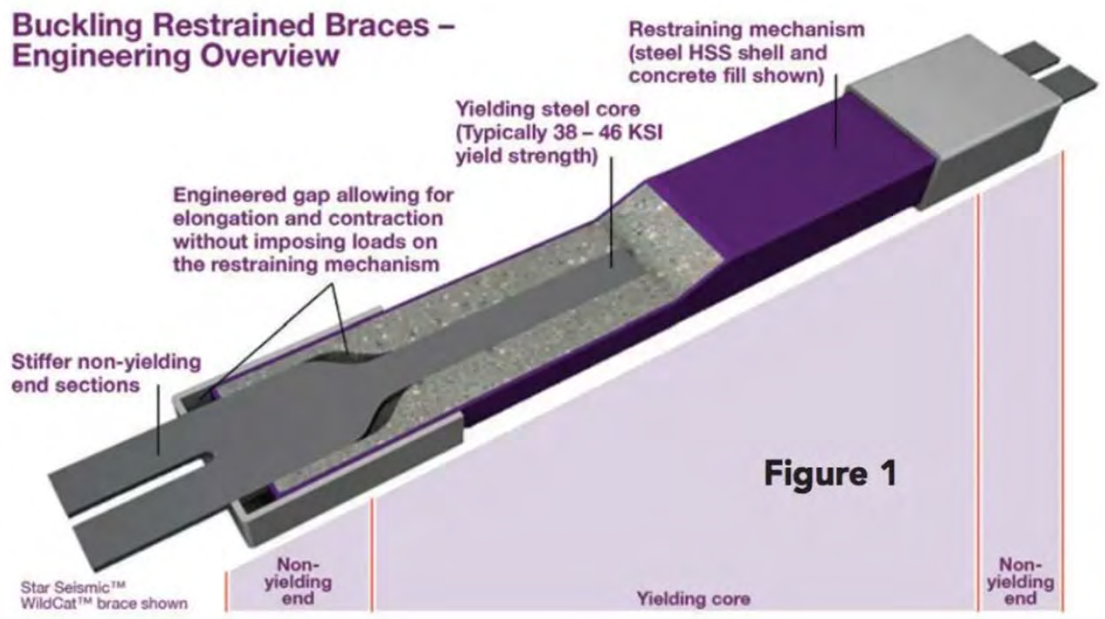


Figure 1: Retrofit performance comparison. Note that while both damping and strengthening reduce drift, only damping reduces drift while simultaneously reducing base shear.



Seismic Retrofits – Viscous Dampers

Seismic Retrofits – Buckling Restrained Braces



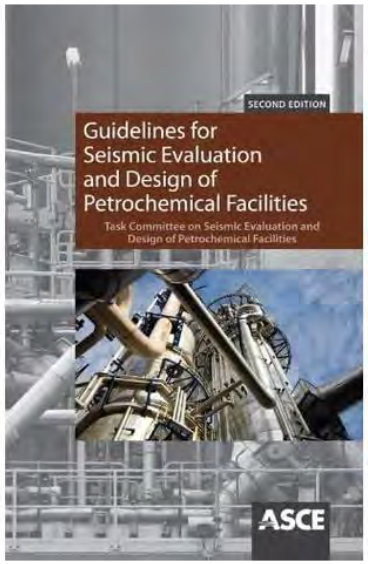
Seismic Retrofits – Fiber Reinforced Polymer (FRP)

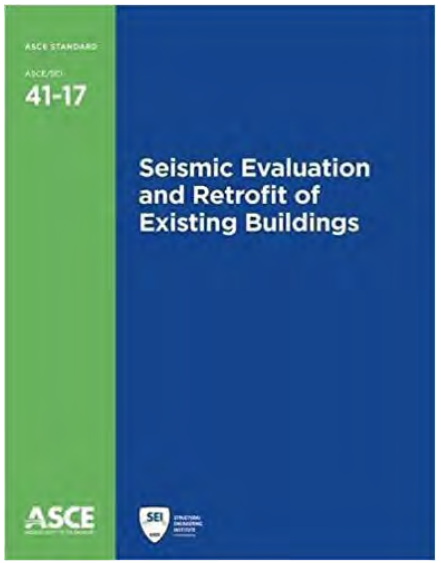
Seismic Retrofits – Shear Walls

Seismic Retrofit?

Summary

- Structural surveys can quickly identify most hazards/deficiencies
- Seismic retrofits can be customized to mitigate specific risks or performance objectives
- Seismic Retrofit Benefits:
  - Increase Safety/Reduce Economic Loss
  - Resume Operation Faster
  - Lower Insurance Rates





Resources

- DNR Seismic Scenarios & HAZUS Reports
  https://www.dnr.wa.gov/seismic-scenarios#list-of-scenarios-for-download

- Liquefaction Hazard Maps
  https://geologyportal.dnr.wa.gov/2d-view#wigm?-13918057,-13091926,5861768,6286758?Earthquakes,Ground_Response,Liquefaction_Susceptibility

- Tsunami Hazard Maps
  https://asce7tsunami.online/

- Tsunami and ShakeAlert Earthquake Early Warning System
  https://mil.wa.gov/alerts

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