URMs in Cascadia

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Cale Ash, S.E.

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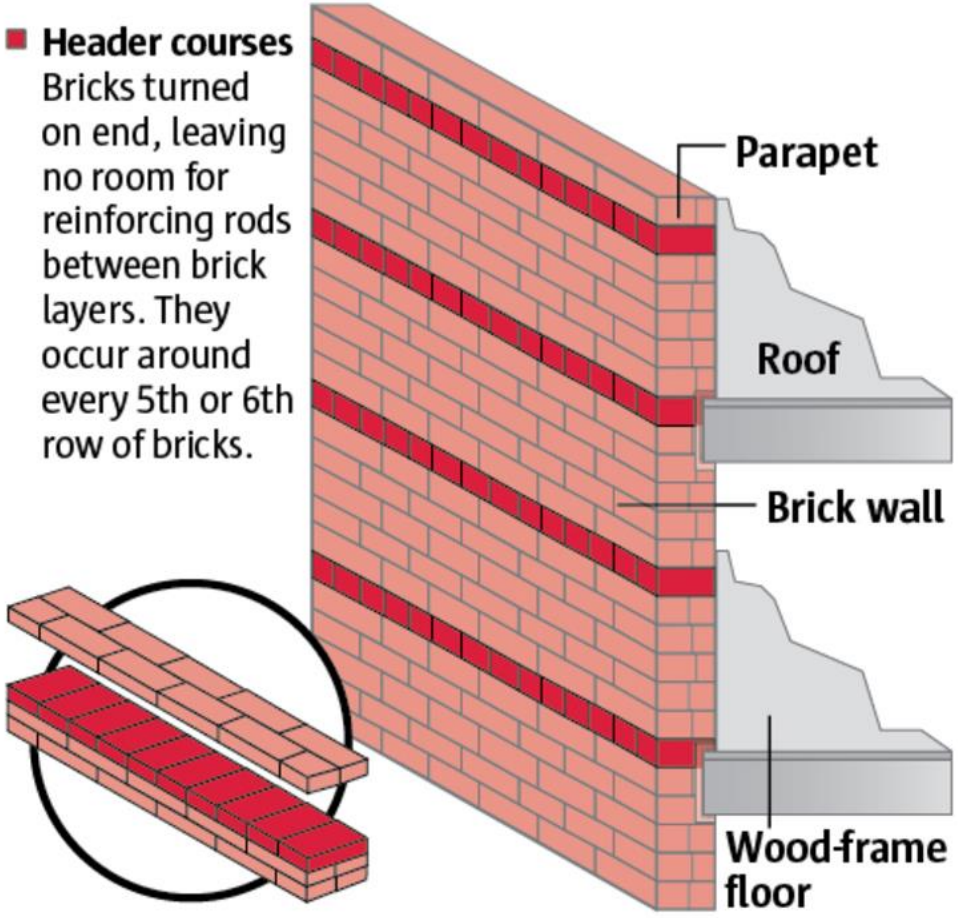
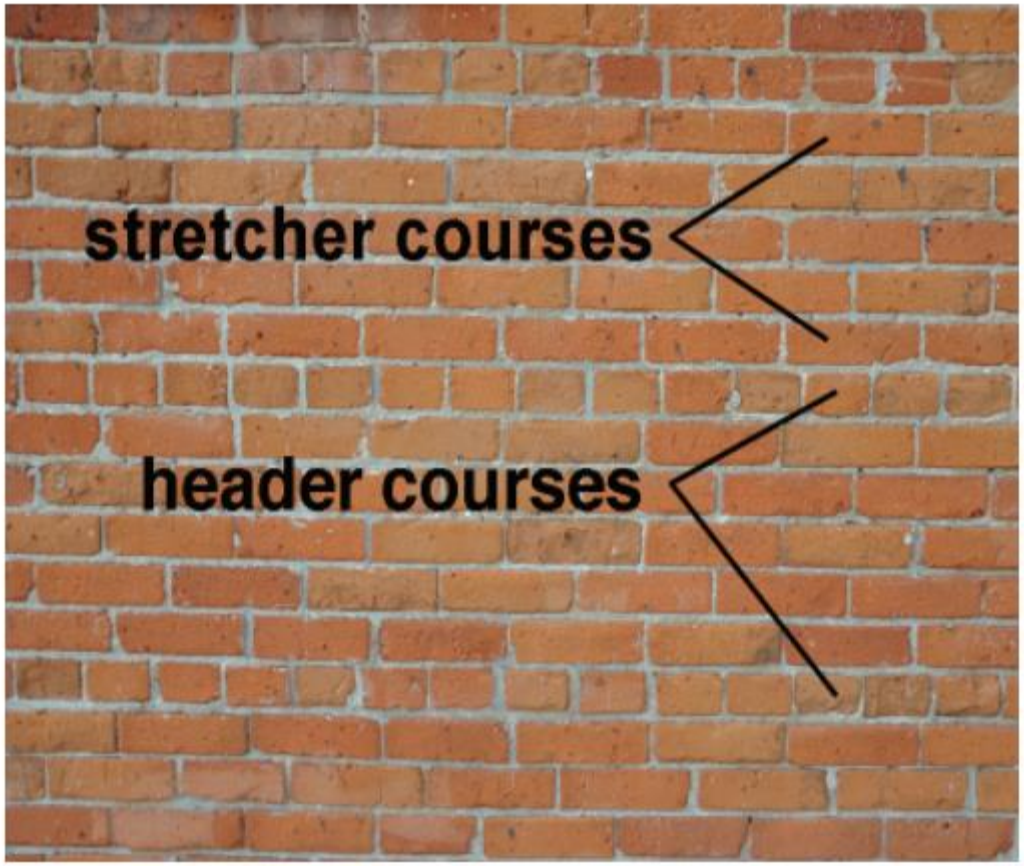
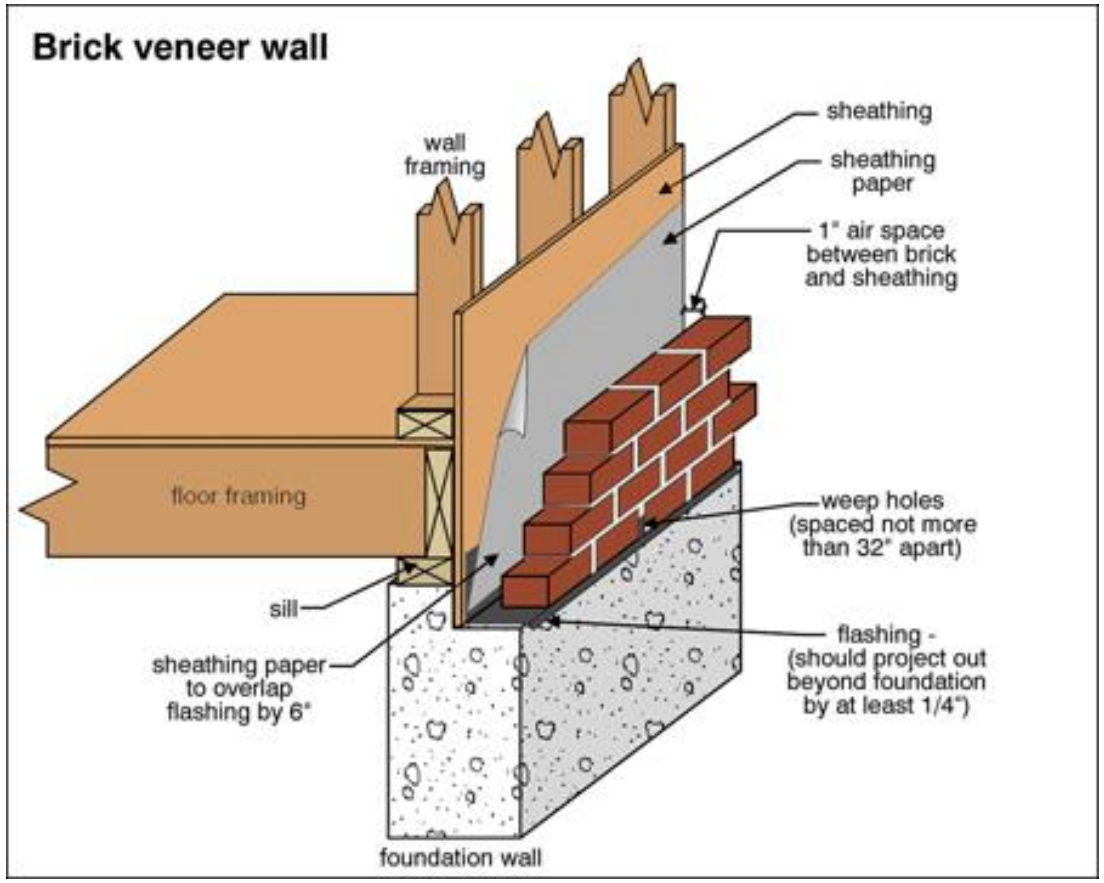
What is a URM


Header courses
Bricks turned on end, leaving no room for reinforcing rods between brick layers. They occur around every 5th or 6th row of bricks.
Parapet
Roof
Brick wall
Wood-frame floor

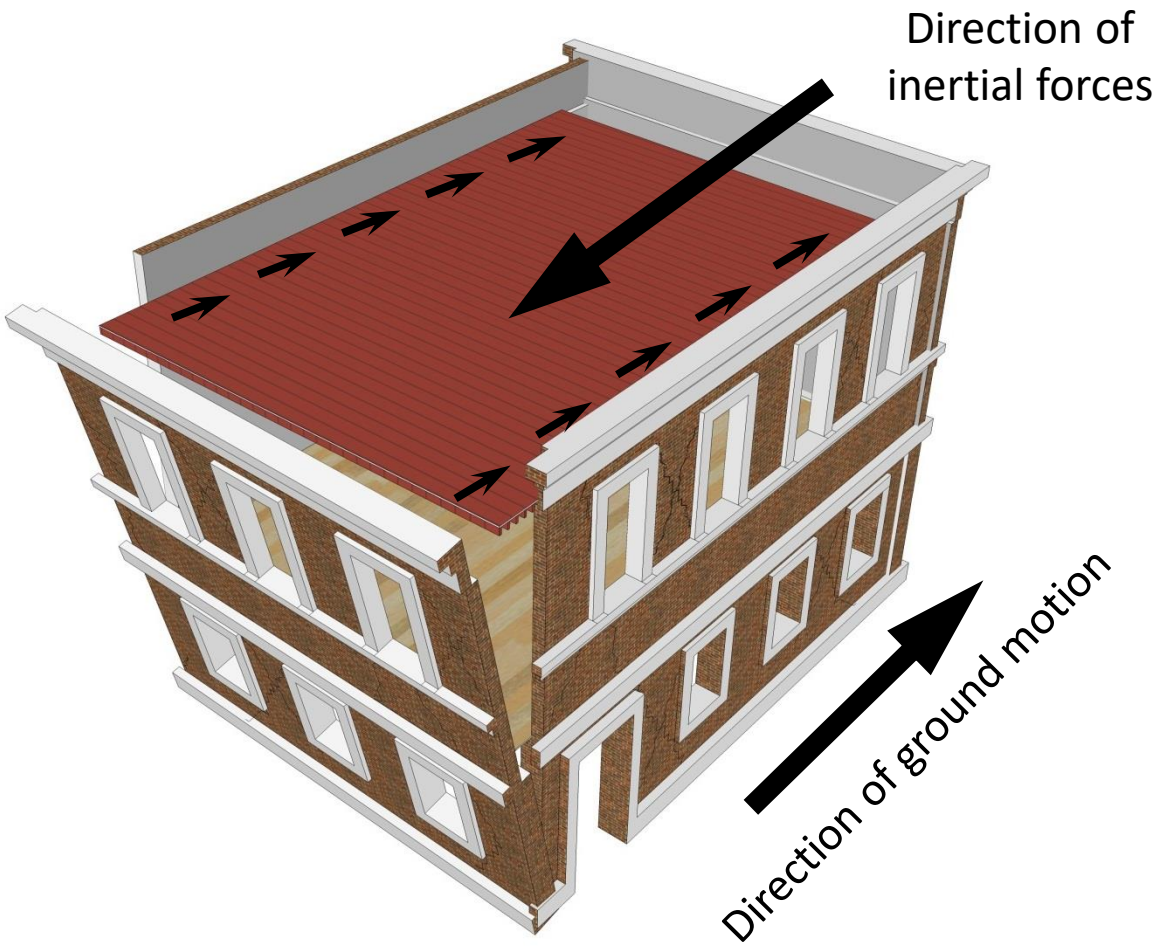

stretcher courses
header courses

Brick Veneer



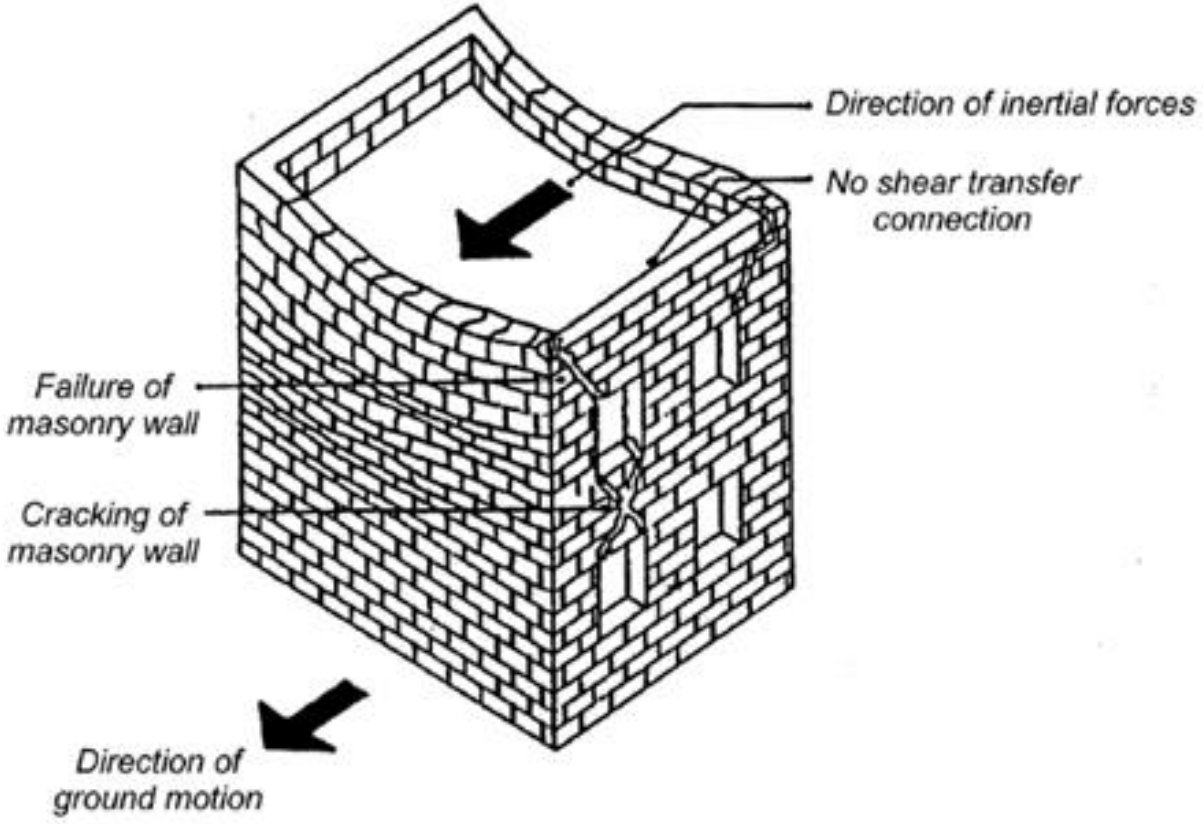


Seismic Load Path



LOAD PATH: OOP Walls >> Tension anchors >> Diaphragm >> Shear Anchors >> In-plane walls

(Courtesy of Prof. Jason Ingham, University of Auckland)



Return wall separation and two way out-of-plane failure (FEMA 306, 1998)

URM – High Occupancy Buildings









URM – Government Buildings



Court House

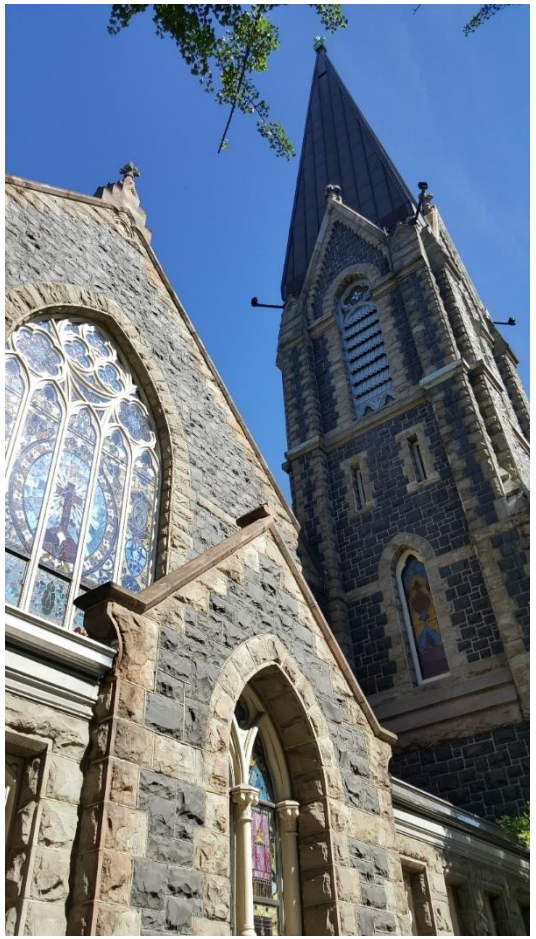


City Hall

URM – Monumental Buildings



Train Station





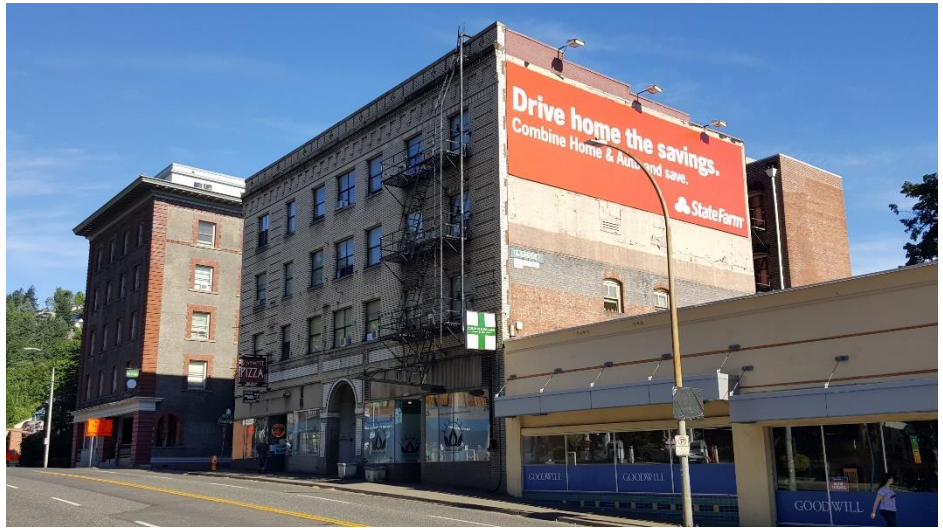
Church

URM – Housing






ONE WAY
ONE WAY
SALAD WORLD


Drive home the savings.
Combine Home & Auto and save.
StateFarm
GOODWILL
GOODWILL
GOODWILL

URM – Commercial









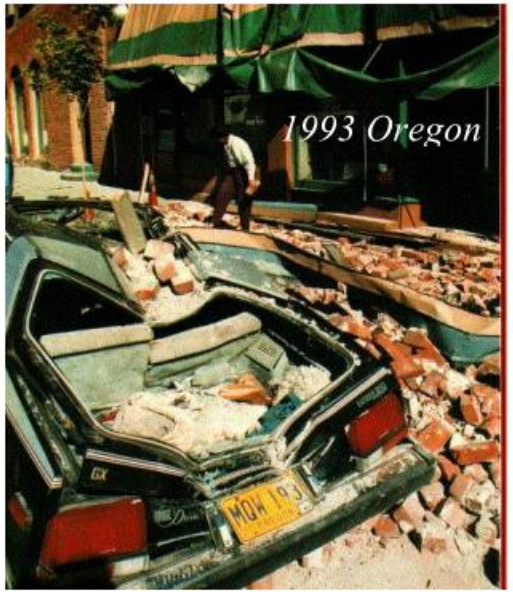
URM Performance in US Earthquakes













URM Performance in PNW Earthquakes

- March 25, 1993 Scotts Mills Earthquake

The Seattle Times
Winner of Nine Pulitzer Prizes

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Thursday, March 25, 1993 - Page updated at 12:00 AM

E-mail article Print

Quake Cracks Oregon Capitol -- Temblor Registers 5.4, Causes Minor Injuries

AP: Times Staff

PORTLAND - An earthquake centered in the Cascade foothills east of Silverton rattled northwest Oregon and parts of Western Washington early today, cracking the rotunda of the Oregon Capitol in Salem and causing minor injuries.

The quake, focused about 12 miles deep and about 30 miles southeast of Portland, registered 5.4 on the Richter scale of ground motion at 5:34 a.m. and lasted about 45 seconds.

"It felt like I was on a boat going down rapids. It woke me right up," said Bill Holder, a cook at Rod's Lafayette Restaurant in Lafayette, near the epicenter.

The original wing of the state Capitol in Salem was closed after serious cracks were found in the rotunda, House Speaker Larry Campbell said. A newer wing remained open. Engineers were considering removing the gold-plated pioneer statue on top of the Capitol.

Two people came to the emergency room at Salem Hospital with minor cuts from falling glass.

In Molalla, 27 miles southeast of Portland, two walls at the high school partially collapsed. Bricks and a chimney fell from the school, which was built in 1925.

Brick planters and windows also were broken at some homes and businesses in the town of 3,800, and goods were knocked off grocery store shelves.





URMs in Scotts Mills

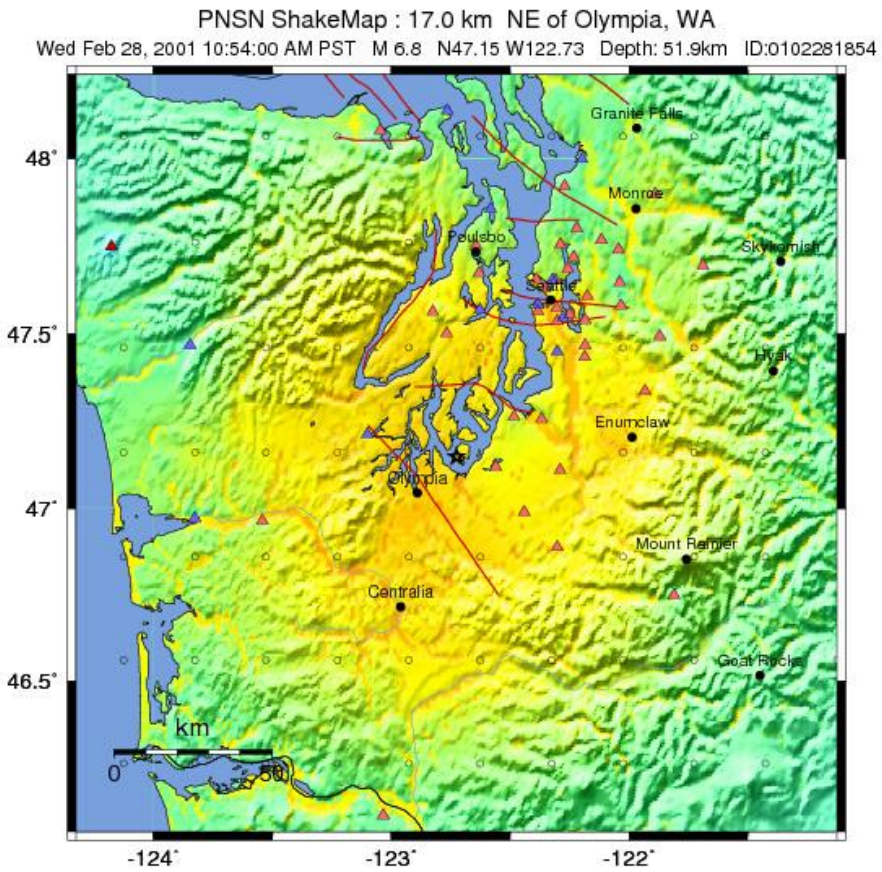




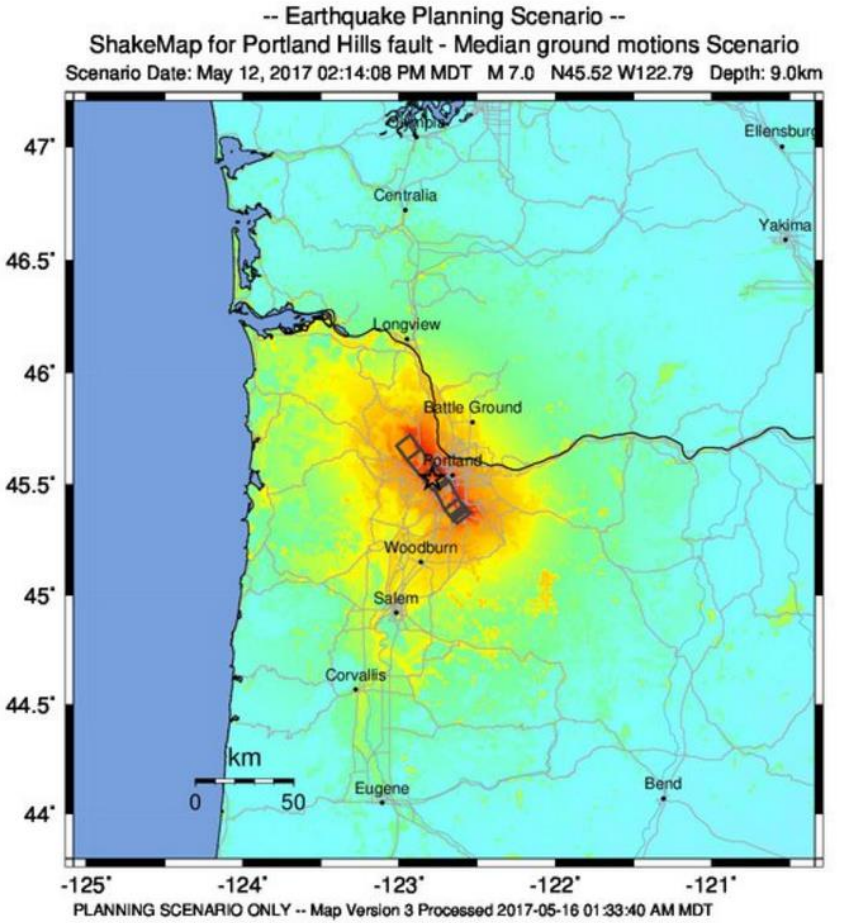


Examples of parapet and roof anchor failures in Scotts Mills, OR Earthquake of 1993 (Dominic Kelly)

URMs in Nisqually (2001, M6.8)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

URMs in Nisqually





URMs in Nisqually









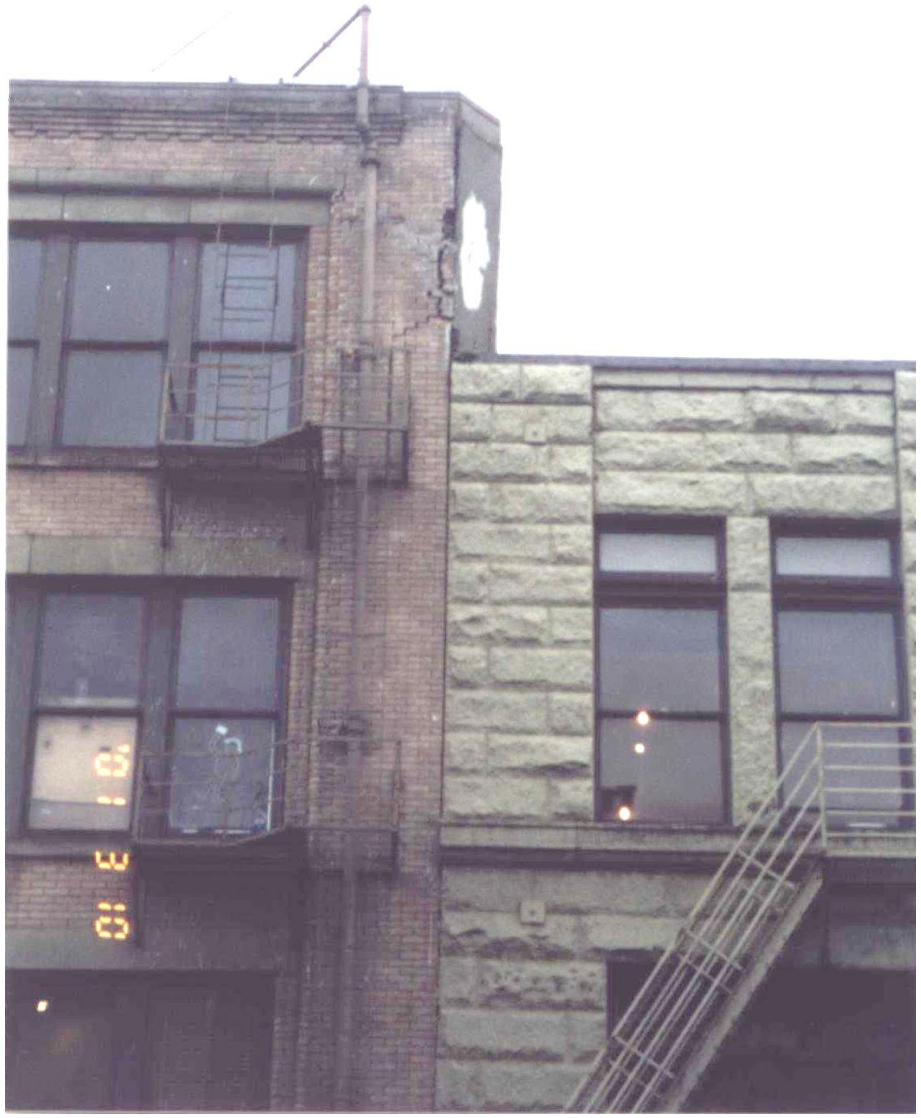
URMs in Nisqually





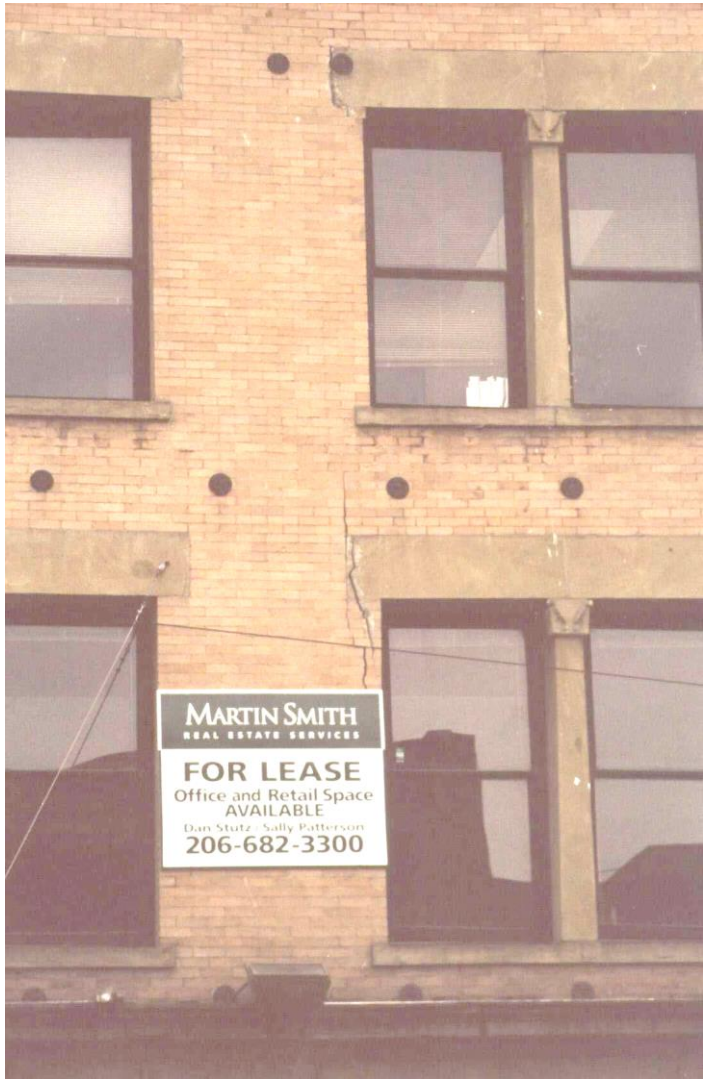
URMs in Nisqually





URMs in Nisqually

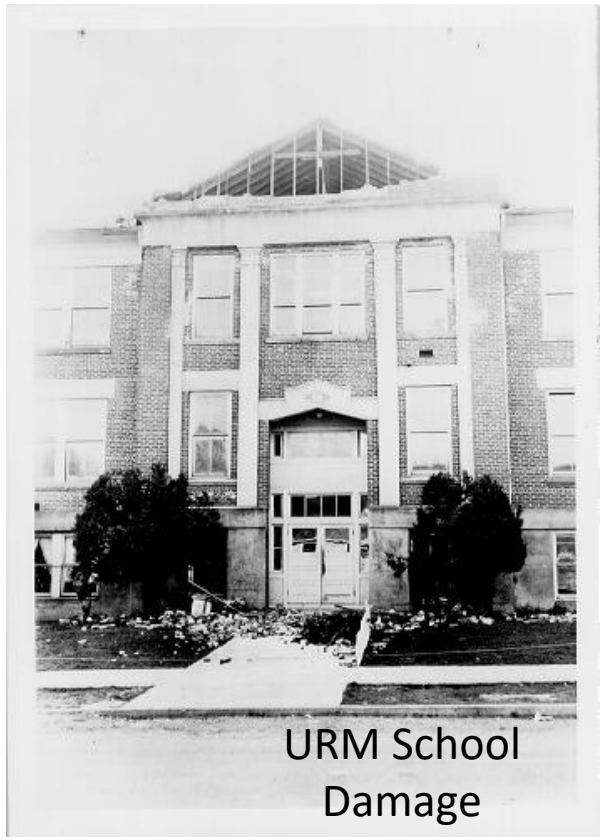




URM School Performance

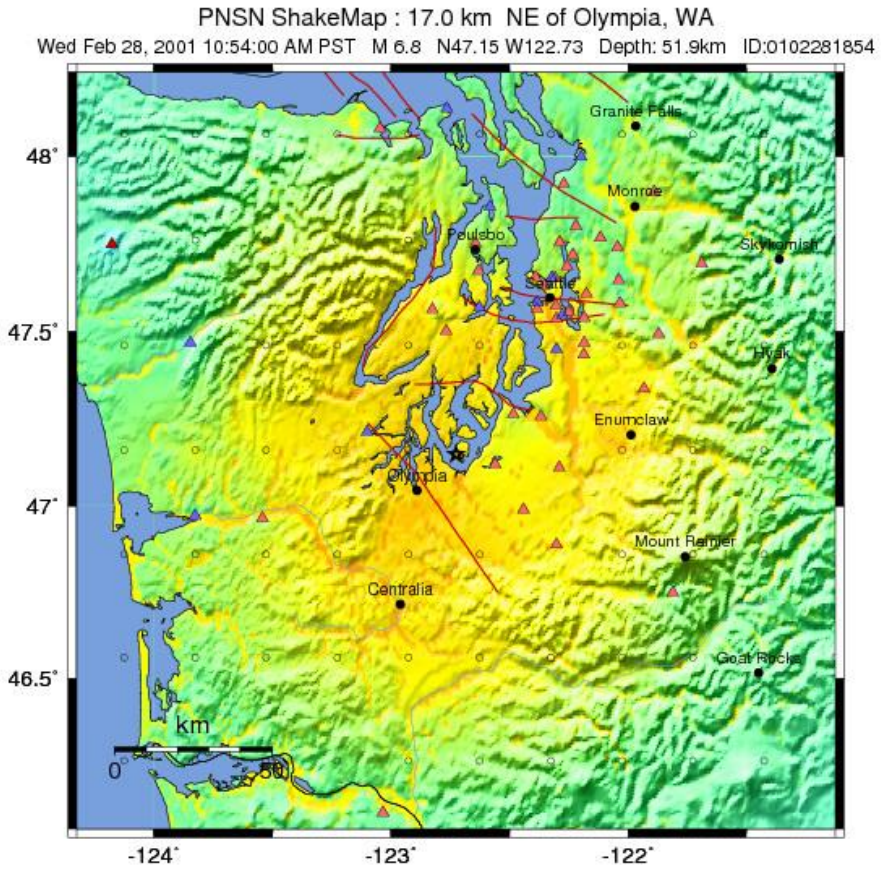


URM Mollala High School Damage
Mollala, OR (1993)



URM School
Damage
Seattle, WA
(1949)

Nisqually Comparison to 2011 Christchurch



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PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
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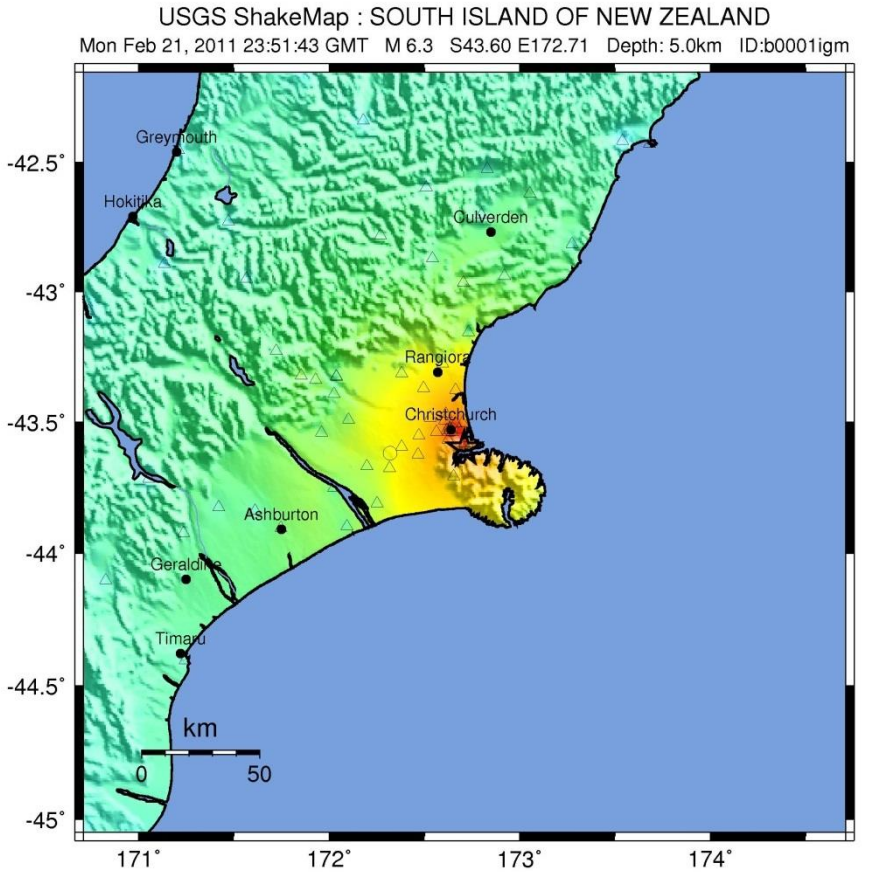
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

URM Commercial Buildings



URM Commercial Buildings



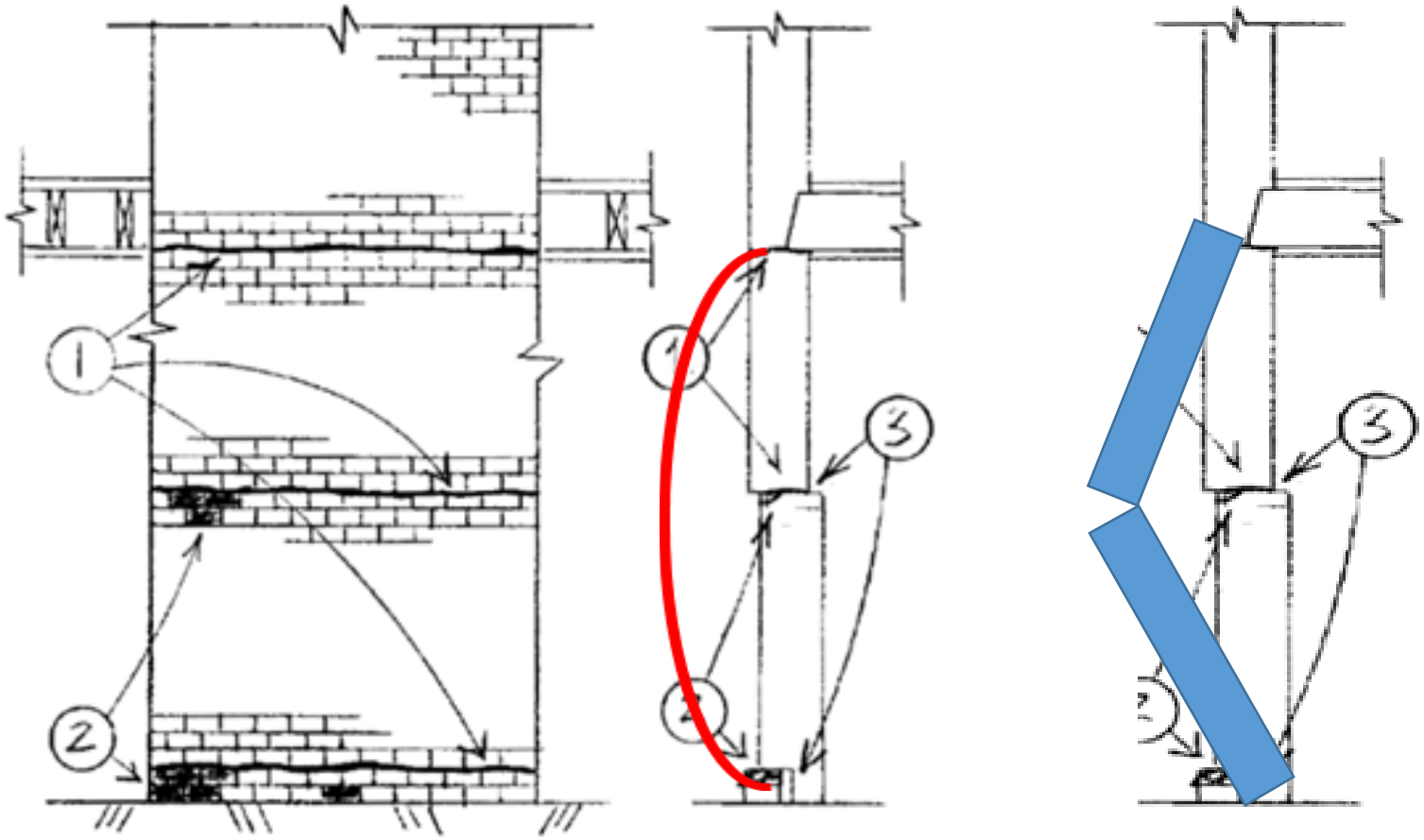
Historic Buildings



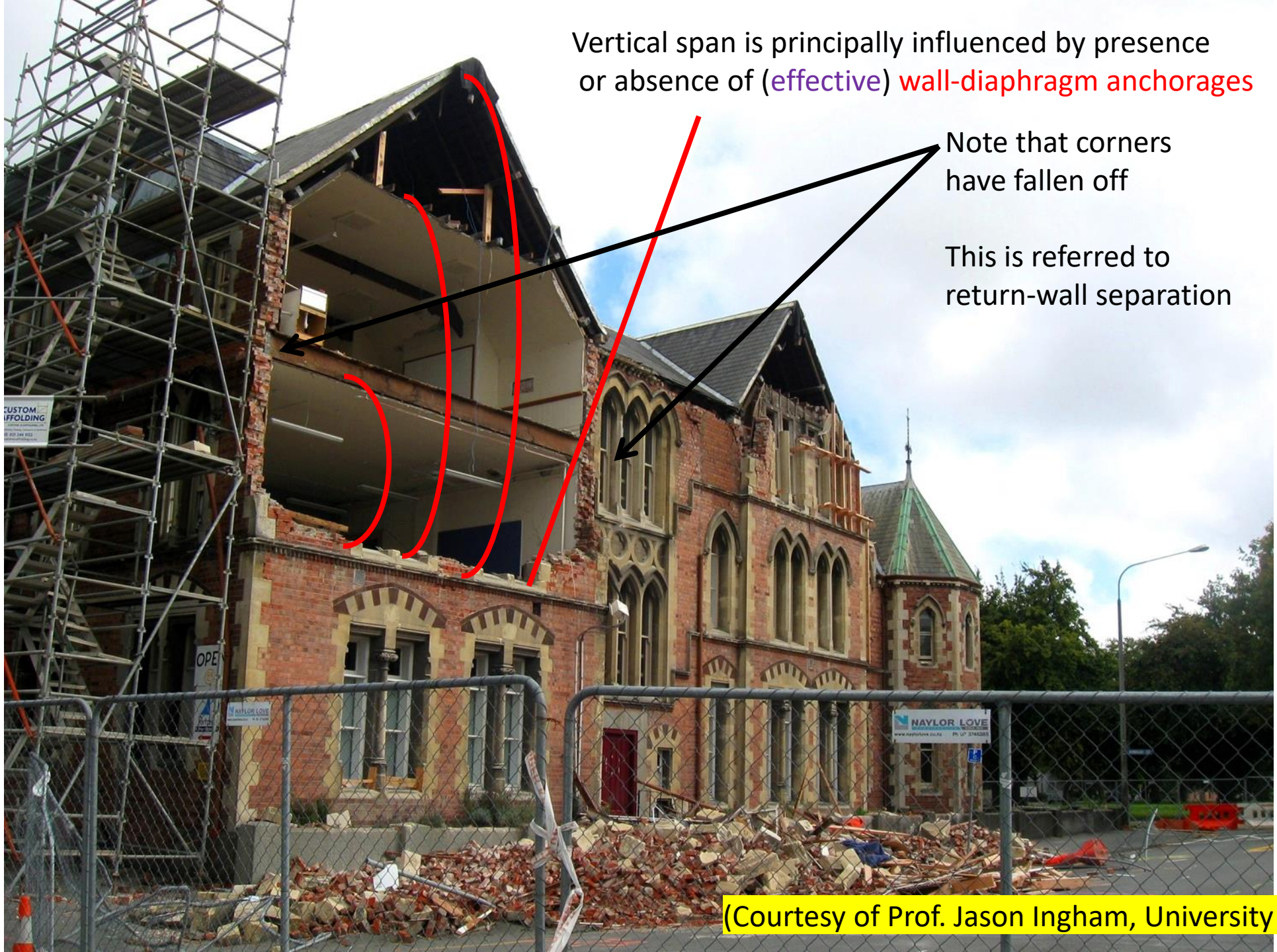
Commercial Buildings



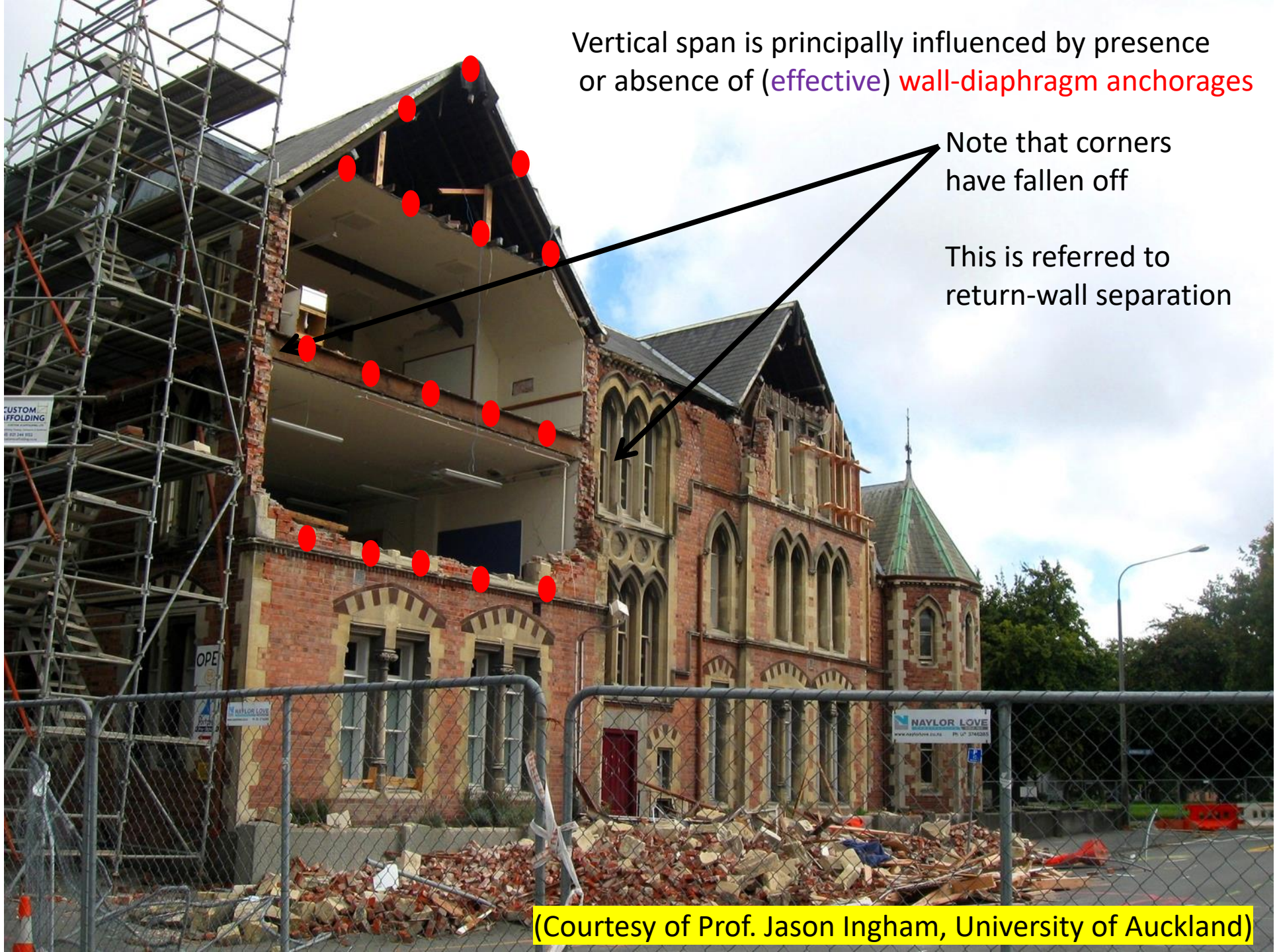
URM Out-of-Plane Bending



- One-way bending (2 supports) is the lower bound value for situations where 3 or 4 edge supports may exist

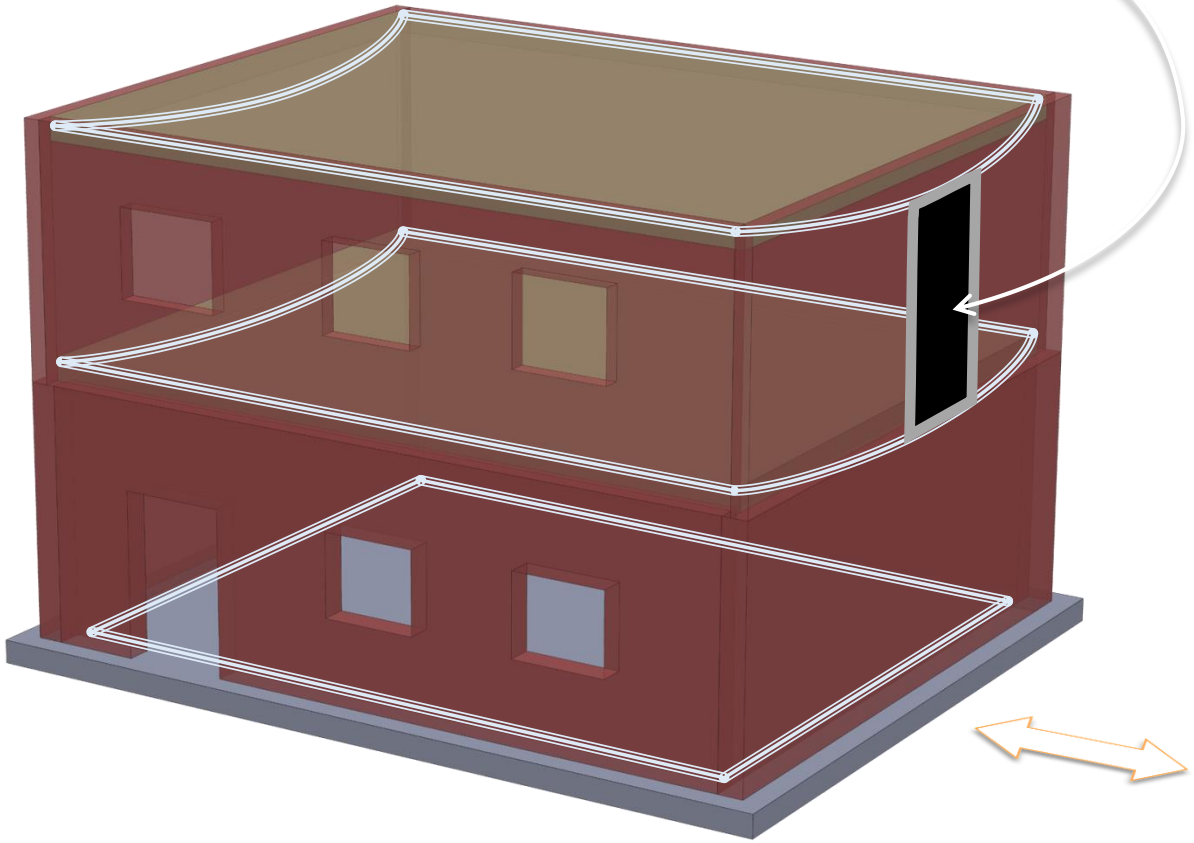


(Courtesy of Prof. Jason Ingham, University of Auckland)


Vertical span is principally influenced by presence or absence of (effective) wall-diaphragm anchorages
Note that corners have fallen off
This is referred to return-wall separation
(Courtesy of Prof. Jason Ingham, University of Auckland)

Experimental Testing (UBC)

Upper-storey wall connected to flexible diaphragms

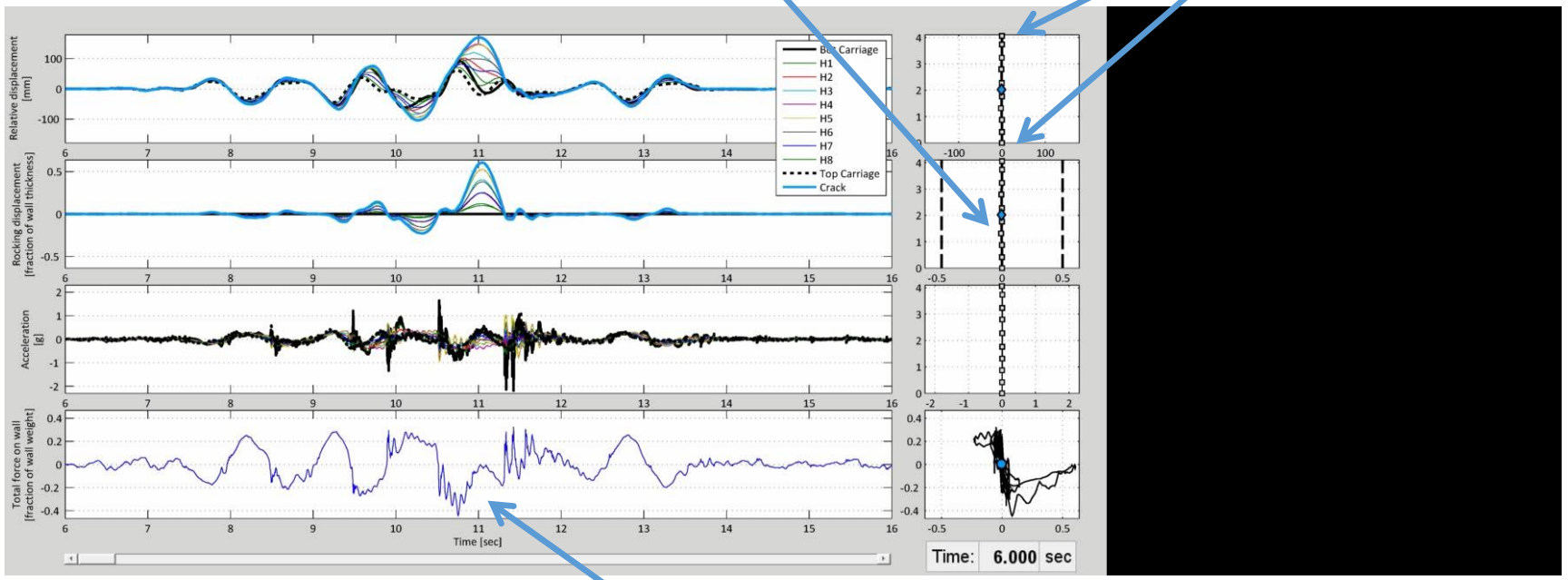


(Courtesy of Prof. Ken Elwood and Prof. Jason Ingham, Univ. of Auckland)

Experimental Testing

Rocking displacement

Diaphragm movement



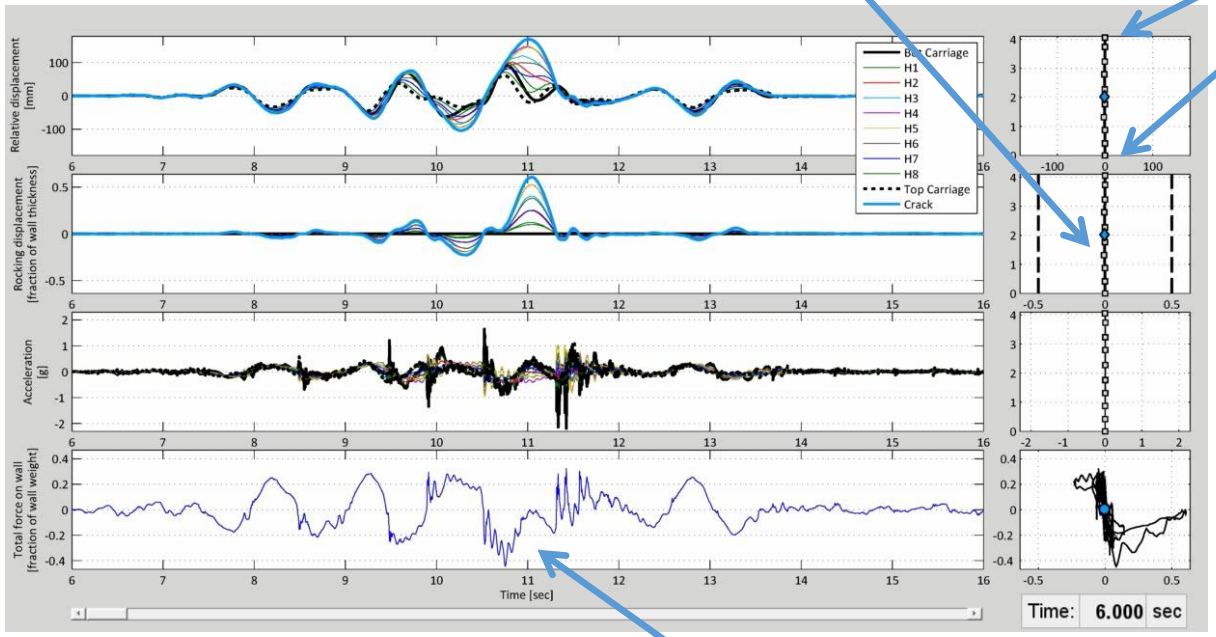
Force on wall
(demand on wall-diaphragm connections)

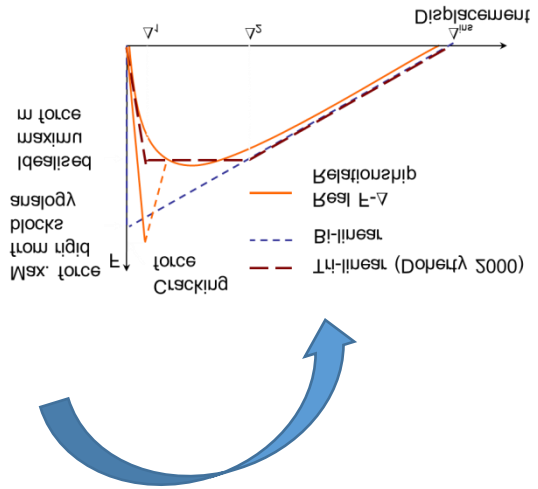
(Courtesy of Prof. Ken Elwood and Prof. Jason Ingham, Univ. of Auckland)

Experimental Testing

Rocking displacement

Diaphragm movement

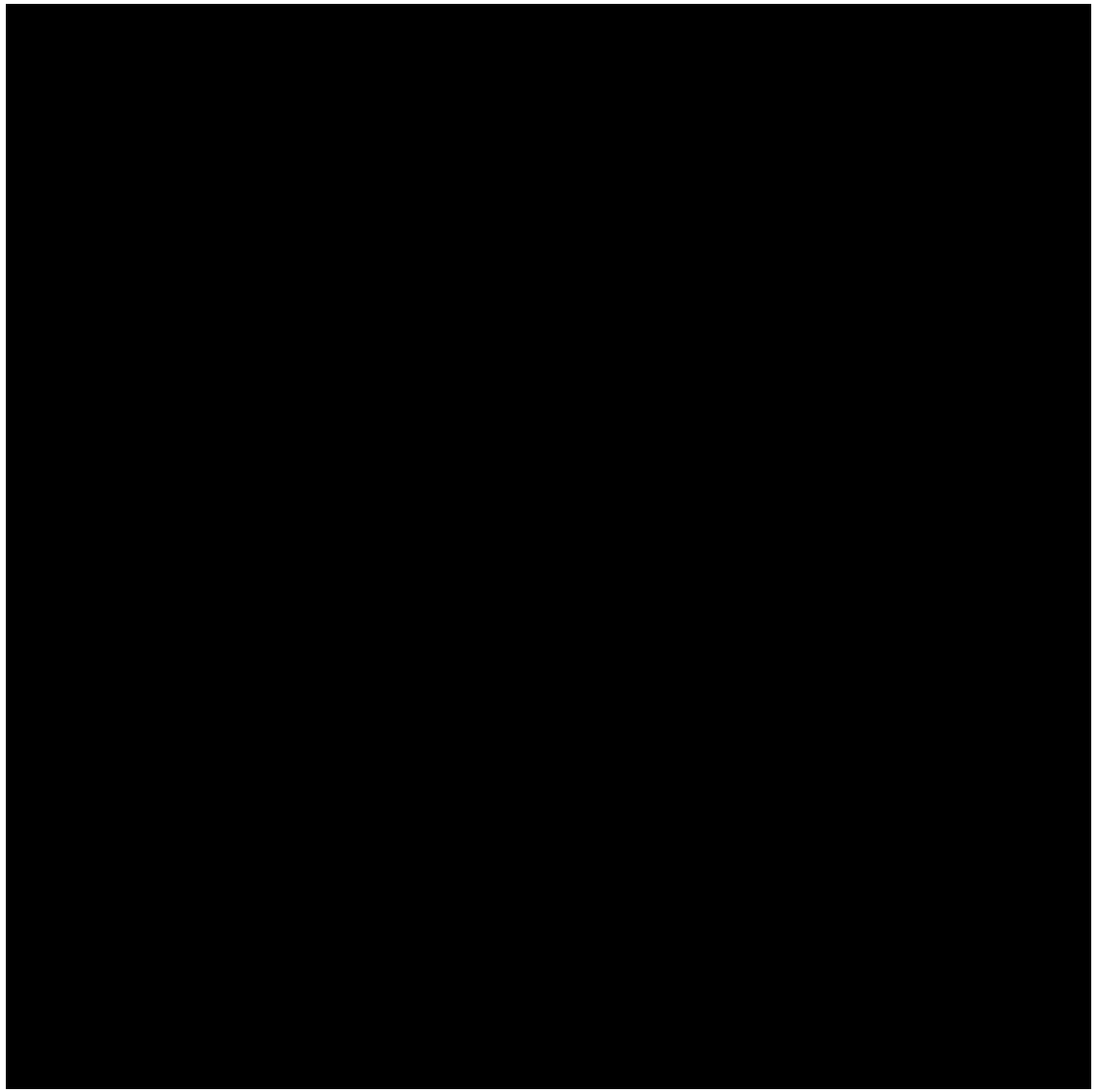




Force on wall
(demand on wall-diaphragm connections)

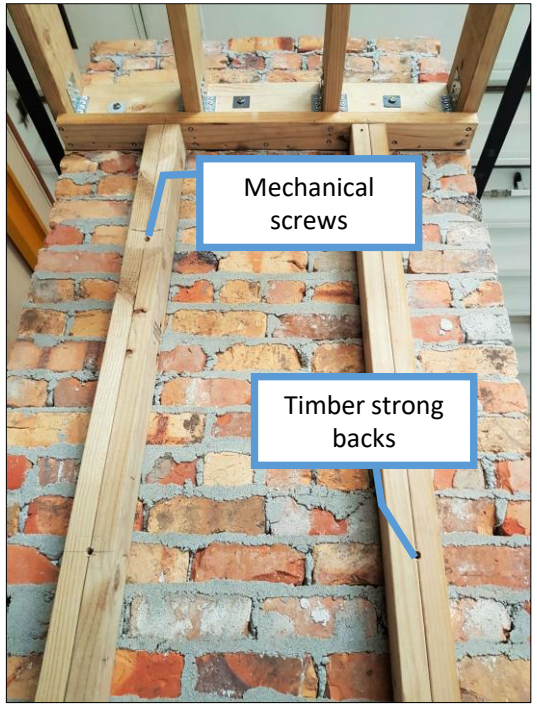
(Courtesy of Prof. Ken Elwood and Prof. Jason Ingham, Univ. of Auckland)

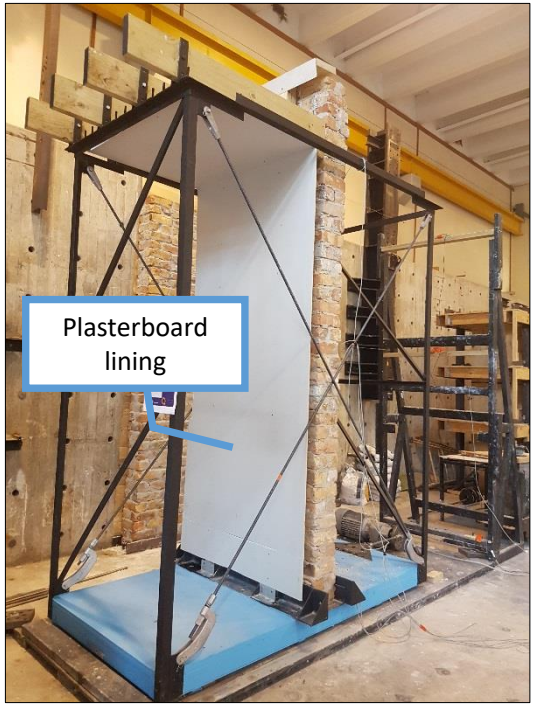
Experimental Testing



(Courtesy of Prof. Ken Elwood and Prof. Jason Ingham, Univ. of Auckland)

Securing of URM walls using timber strongbacks (Dmytro Dizhur)





(Courtesy of Prof. Jason Ingham, University of Auckland)

Securing of URM walls using timber strongbacks (Dmytro Dizhur)









As-built



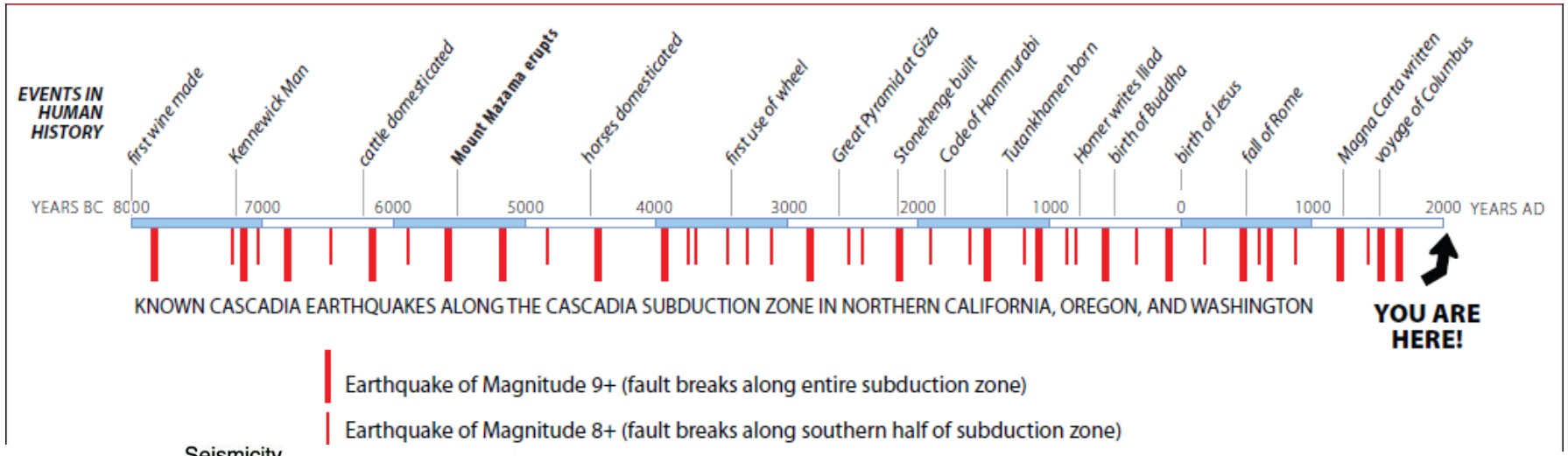
Strongbacks

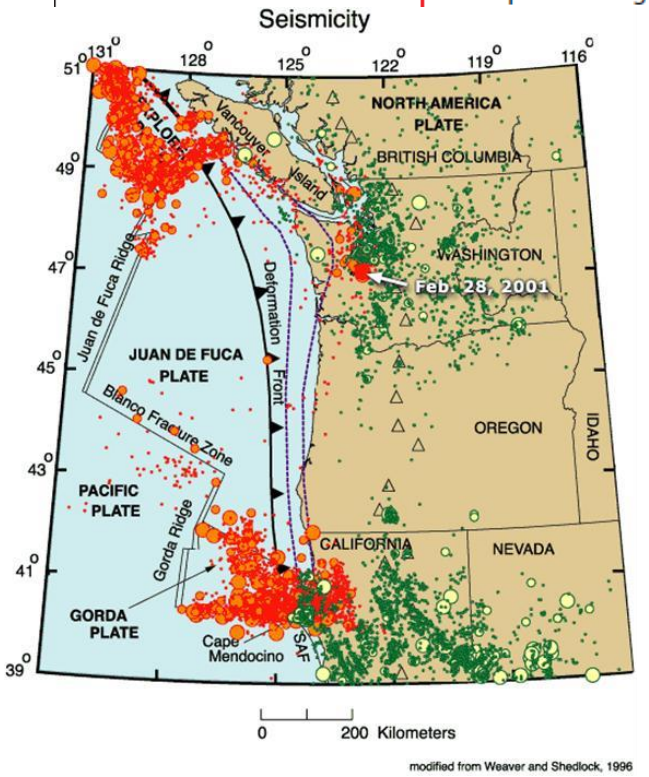


Post-tensioned

(Courtesy of Prof. Jason Ingham, University of Auckland)

Cascadia Subduction Zone







Duration of shaking

After Sept 2010



After Feb 2011



(Courtesy of Prof. Jason Ingham, University of Auckland)

Duration of shaking

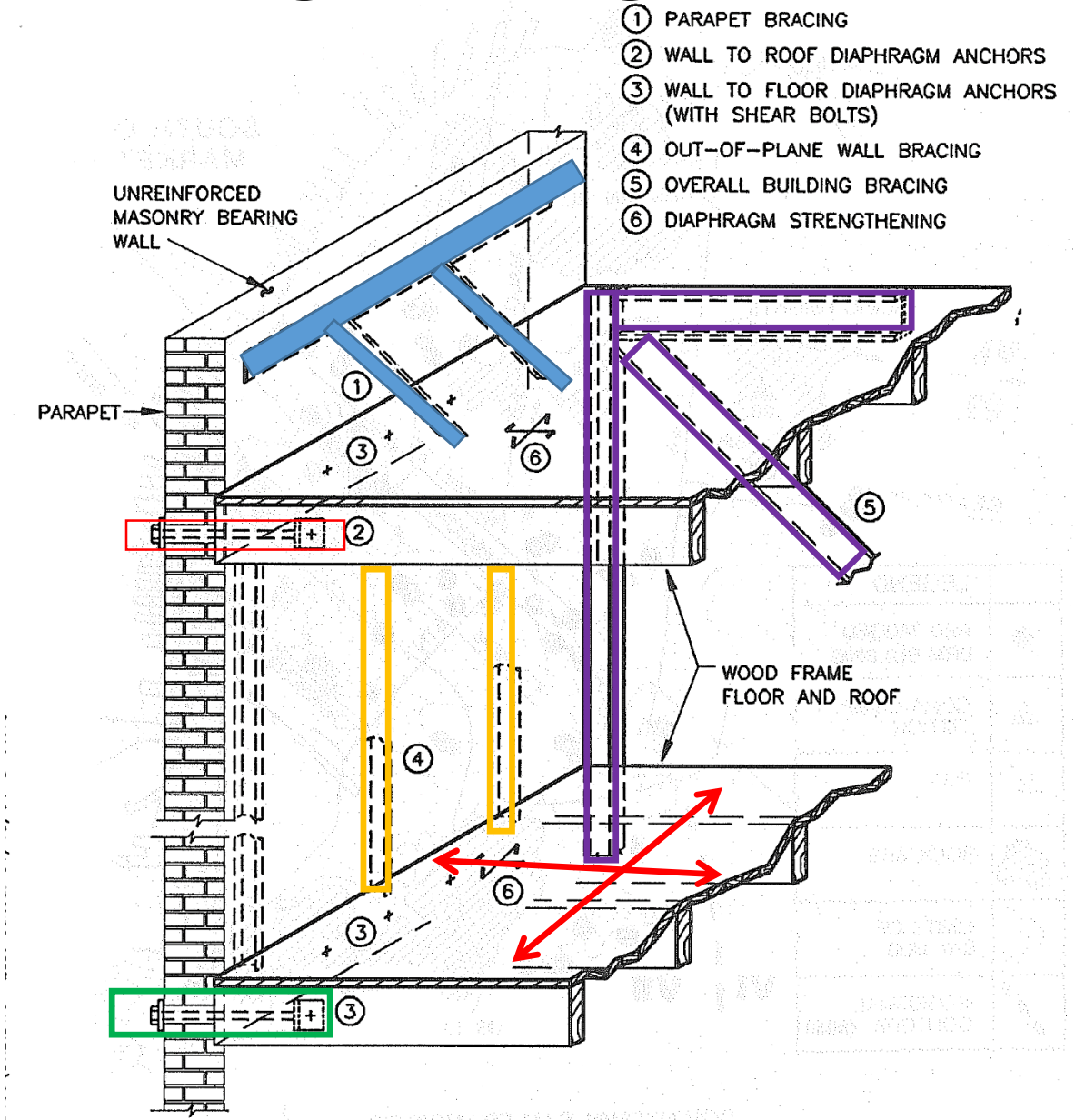






(Courtesy of Prof. Jason Ingham, University of Auckland)

Seismic Strengthening Elements for URM



D. Bonneville and D. Cocke, “Effectiveness of Minimal Seismic Strengthening of Unreinforced Masonry Buildings,” The seismic Retrofit of Historic Buildings Conference, 1991

Apartment Building Retrofit



Apartment Building Retrofit

Parapet bracing





Wall anchorage

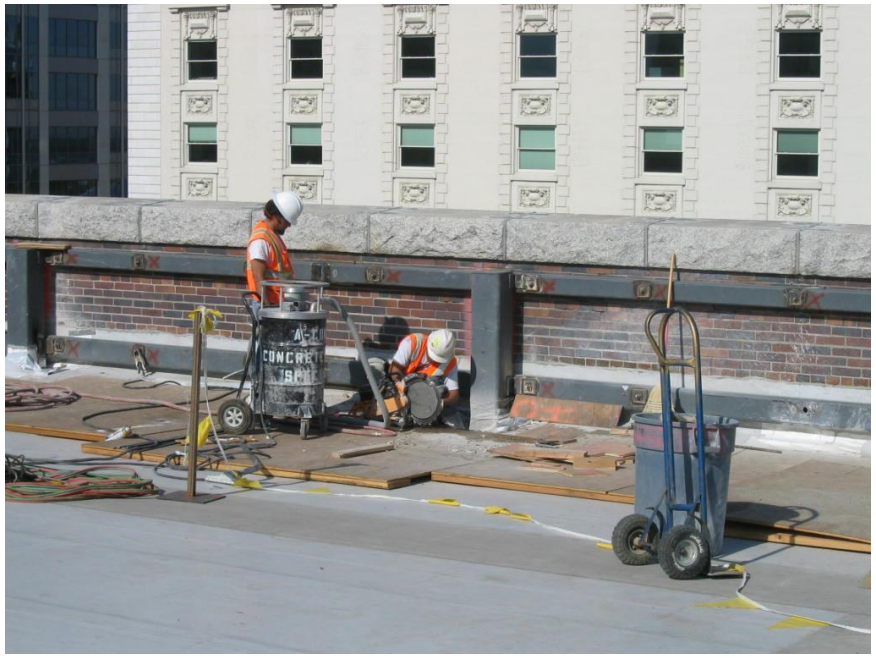
Bracing of parapets



(Courtesy of Prof. Jason Ingham, University of Auckland)

Office Building Retrofit



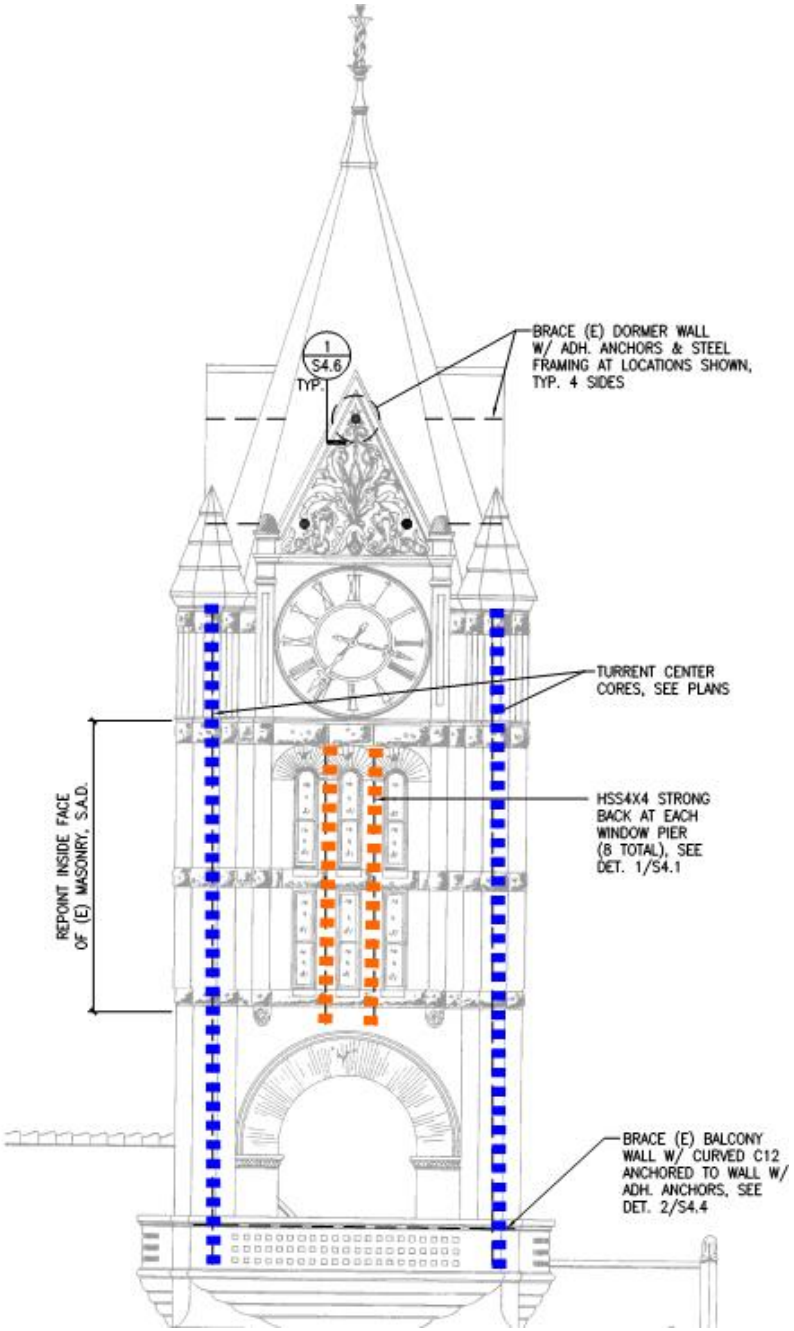




Parapet bracing and Wall Out-of-Plane Strengthening

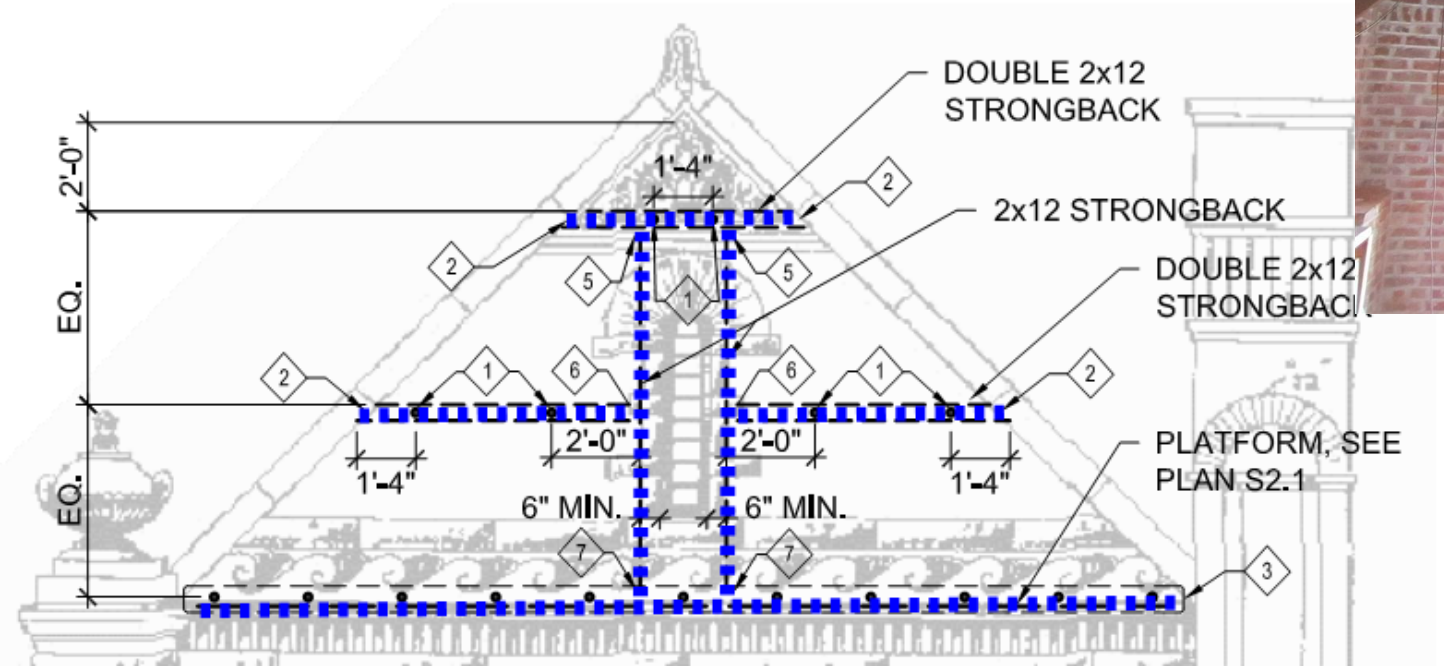
Courthouse Retrofit





Courthouse Retrofit





University Building Retrofit







URM Retrofits



URM Retrofits





URM Retrofits



URM Retrofits



URM Retrofits – Out of Plane Bracing



(a) Internal strong backs to restrain out-of-plane wall failure



(b) Struts from the floor above to improve out-of-plane performance

(Courtesy of Prof. Jason Ingham, University of Auckland)

URM Retrofits – Internal Moment Frame



(a) Post-earthquake condition of a URM building having an internal steel frame retrofit



(b) Reinforced concrete moment frame retrofit

(Courtesy of Prof. Jason Ingham, University of Auckland)

URM Retrofits – Braced Frame



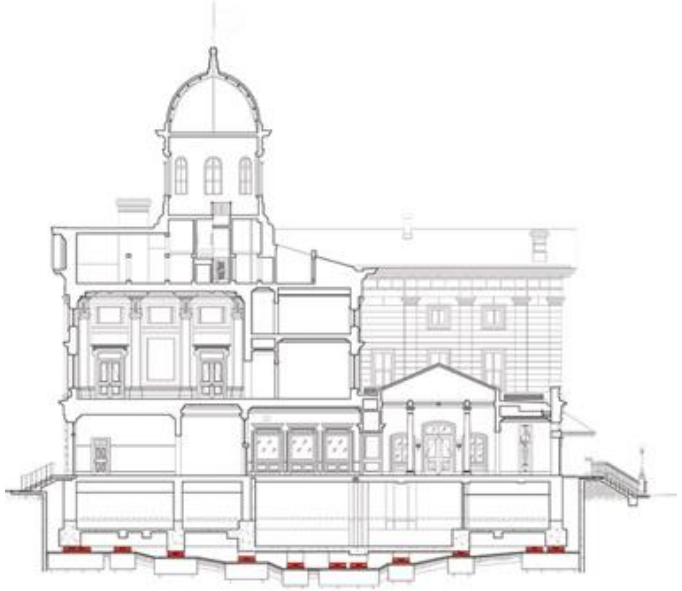
(a) Eccentric bracing in a walkway

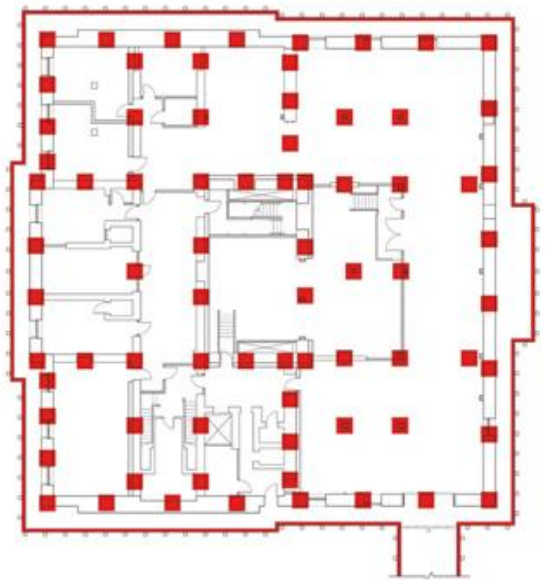


(b) Eccentrically braced core

(photos courtesy of Dunning Thornton Consultants)

URM Retrofits – Base Isolation

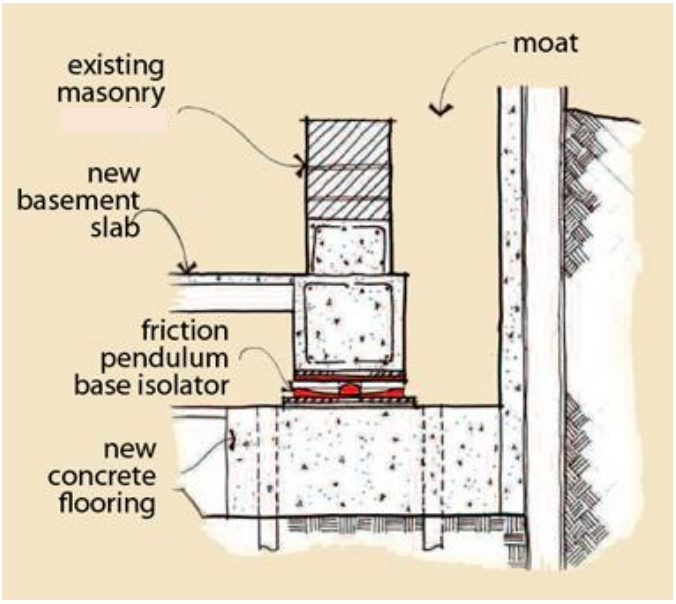




Oregon Pioneer Court House







(Source: http://pioneercourthouse.org/seismic-upgrade.html)

Why Act – Resilience Role



Source: Carmen Merlo



Light Rail Tracks

Why Act – Resilience Role

- Oregon Resilience Plan

> ▶ **Accelerate the Retirement or Full Upgrade of Vulnerable Buildings** (Chapter 4 Critical and Essential Buildings)
>
> - *Finding:* Unreinforced Masonry (URM) and non-ductile concrete buildings are generally the most dangerous types of buildings in an earthquake, and should not be allowed to remain in service indefinitely unless they are fully upgraded.
>
> - *Recommended:* Initially, the danger of URM and non-ductile concrete buildings should be disclosed at the time of building sale or lease. Through market pressures and upgrades triggered by other building repairs and changes, upgrades can be made to many of these structures.

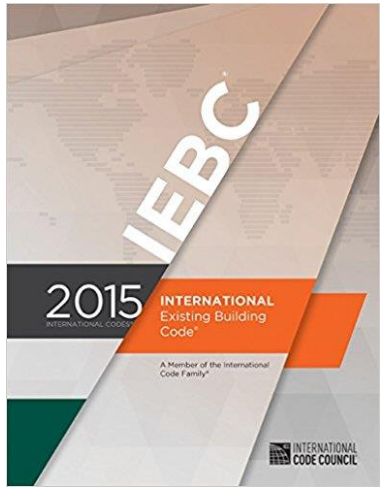
- Resilient Washington State

> **3c.** Provide model code language for adoption by local jurisdictions in order to ensure that unsafe buildings do not kill or injure occupants. This should include mandatory parapet retrofit (or removal); examining the City of Seattle's Unreinforced Masonry (URM) building retrofit ordinance; and working with stakeholders to identify federal, state, and local incentives to promote adoption and action (e.g. retrofitting).

Codes & Standards

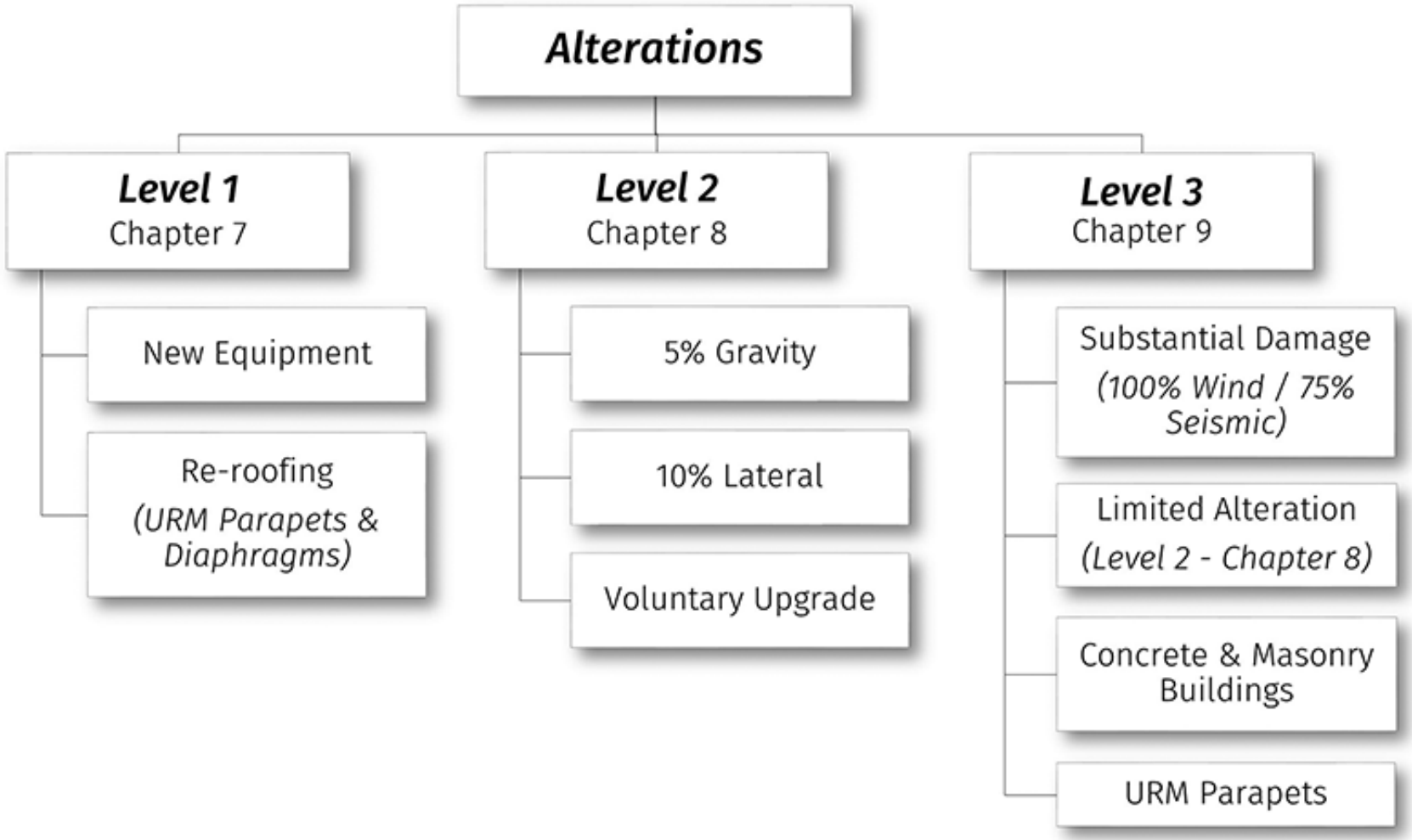
- Oregon & Washington adopt the International Building Code
  - 2014 Oregon Structural Specialty Code (based on 2012 IBC)
  - 2015 IBC currently used in Washington
- Both States also adopt versions of the International Existing Building Code (IEBC)
- Seismic Evaluation Standards
  - ASCE 41 – American Society of Civil Engineers







Code Triggers – 2015 IEBC

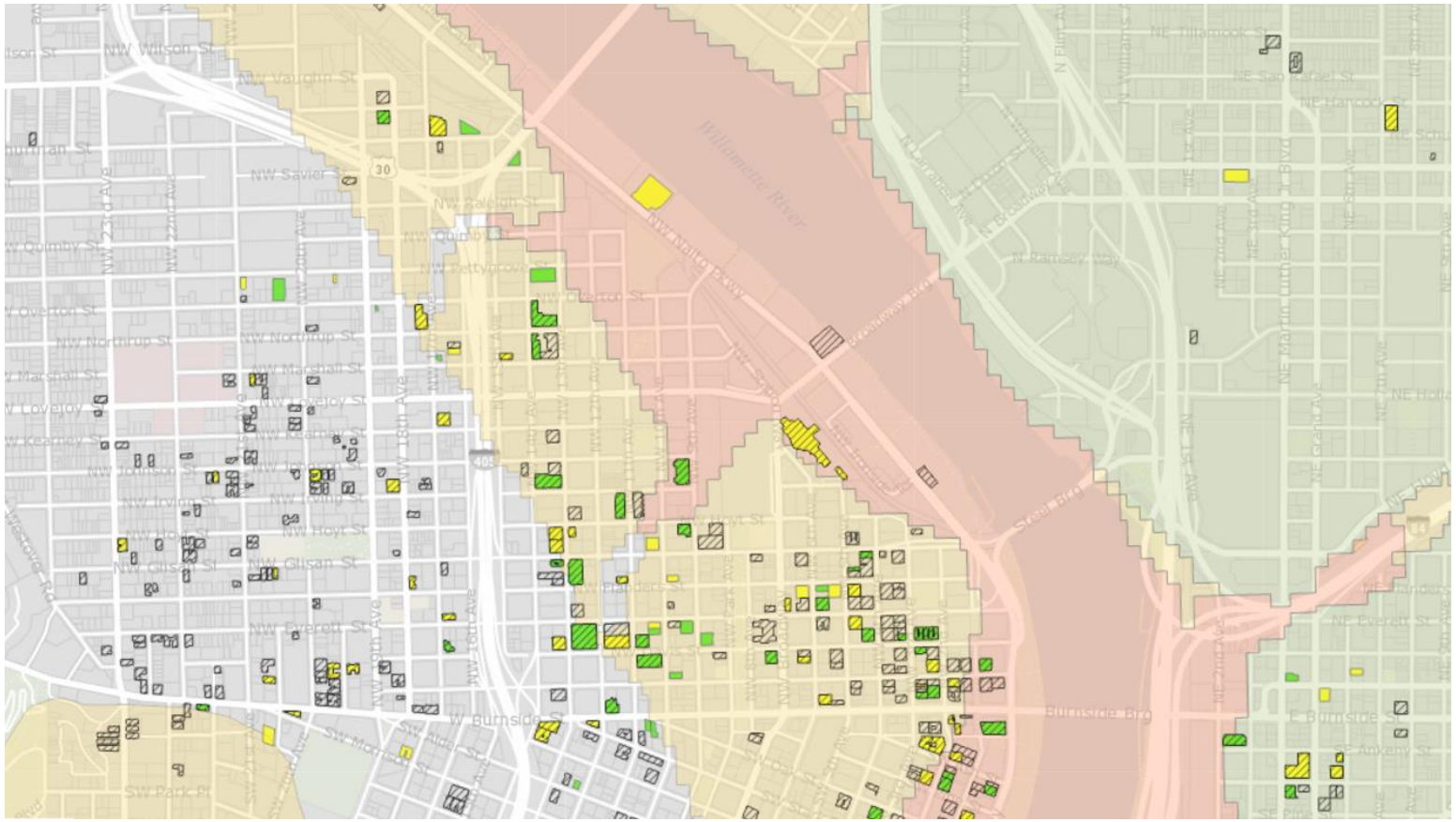


Code Triggers – Seattle

- Remodeling/additions that extend life of building
- Change in occupancy
- Occupant load increase in URM
- Reoccupying a building vacant for 24 months
- Building repairs >60% of value

1. Complete Seismic Evaluation
2. Propose Retrofit Scope to City

Retrofit Ordinances – Portland & Seattle





Retrofit Ordinances - Seattle

- Technical Provisions Established
- Policy in Legislative Process
- Proposed Timeline
  - Critical Risk – 7 years (schools, hospitals, fire stations)
  - High-Risk – 10 years (> 3 stories on poor soils, > 100 occupants)
  - Medium-Risk – 13 years (remaining URMs)

Incremental Retrofit Strategies

- Brace parapets during re-roofing
  - Some jurisdictions already require this
- Interior renovations
- Energy upgrades
- Occupant turn-over
- Vulnerable features
  - Parapets
  - Egress paths





Funding Opportunities

- FEMA Grants
  - PDM, HMGP for eligible organizations
  - Contact State Emergency Management Office
- Oregon Seismic Rehabilitation Grants
  - Schools & Emergency Services
- Local Incentives

FEMA

Federal Insurance and Mitigation Administration

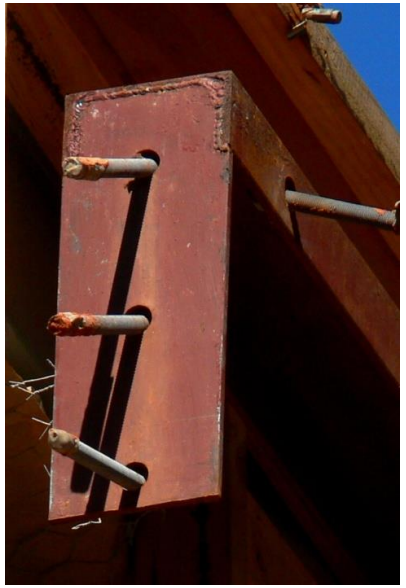
FY 2017 Pre-Disaster Mitigation (PDM) Grant Program



Considerations for Previous Retrofit

- Hazard Level (retrofit prior to 1994)
- Performance Level
  - Retrofit schools to higher performance
  - Substantial Alteration triggered
- QA/QC







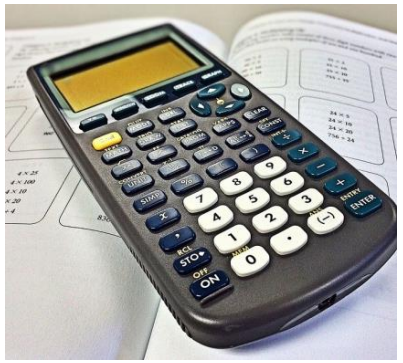
(Courtesy of Prof. Jason Ingham, University of Auckland)

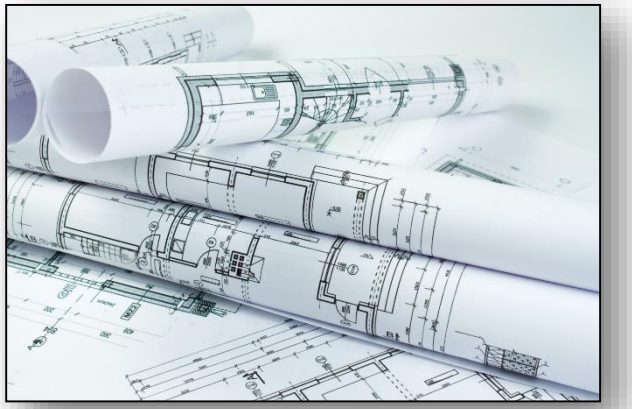
Retrofit Process

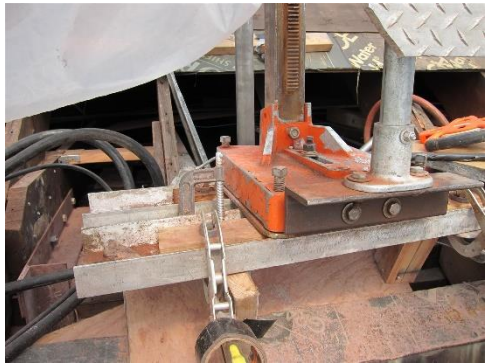
- Tier 1 Evaluation
- Tier 3 Detailed Evaluation
- Material Testing
- Field Investigation
- Understand Soil Conditions
- Design Drawings
- Construction Support













Conclusions

- URMs house a variety of critical services & businesses in Cascadia
- URMs contribute to the character & diversity of our neighborhoods
- Earthquake performance is well-documented
- Variety of retrofit options exist with varying performance levels
- Mandatory retrofit ordinances are coming soon…



