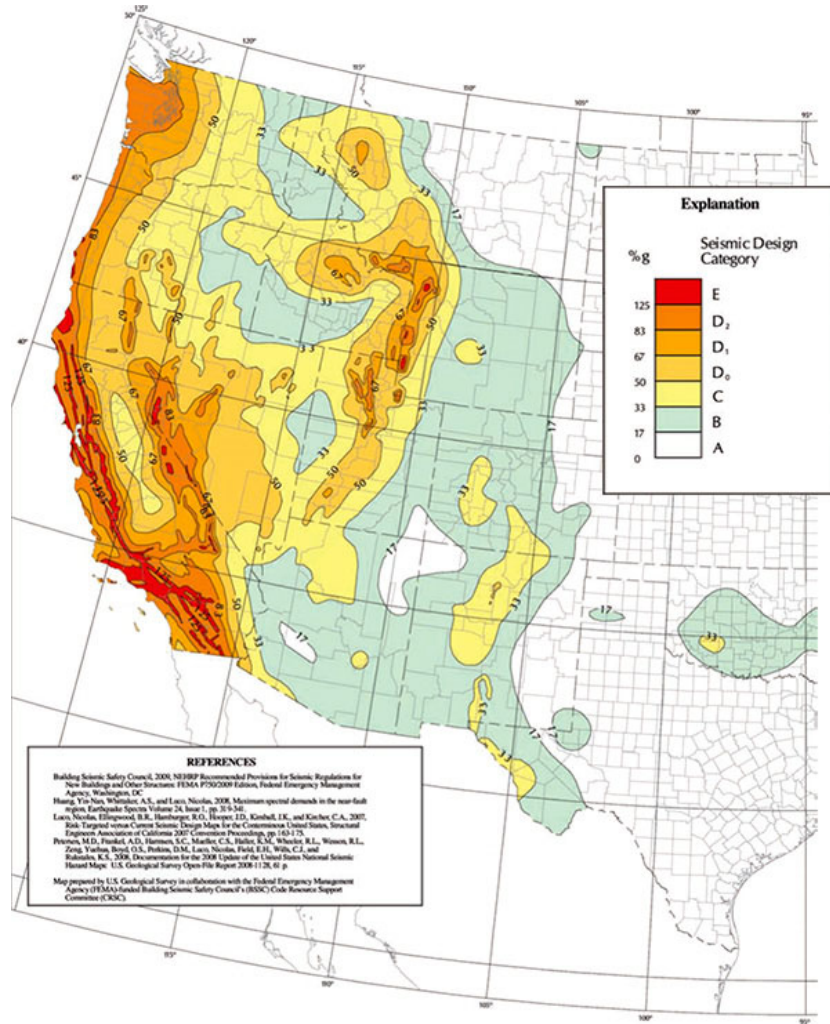


# **Overview of Vulnerable Buildings & Seismic Ordinances**

Erica C. Fischer, PhD, PE

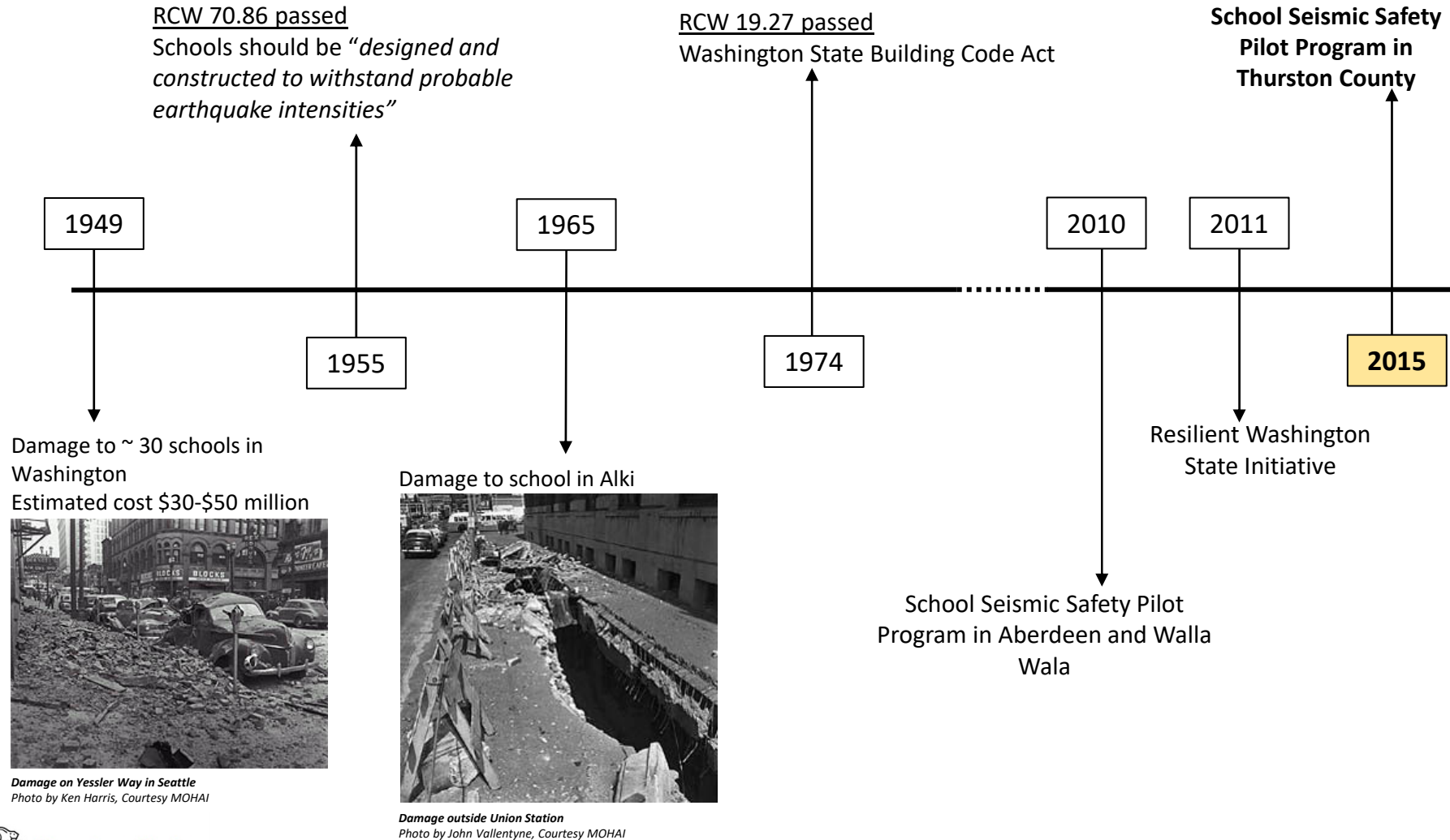
# Washington Seismicity



- Washington state has **second highest** earthquake risk in U.S.
- Increased understanding & awareness of risk

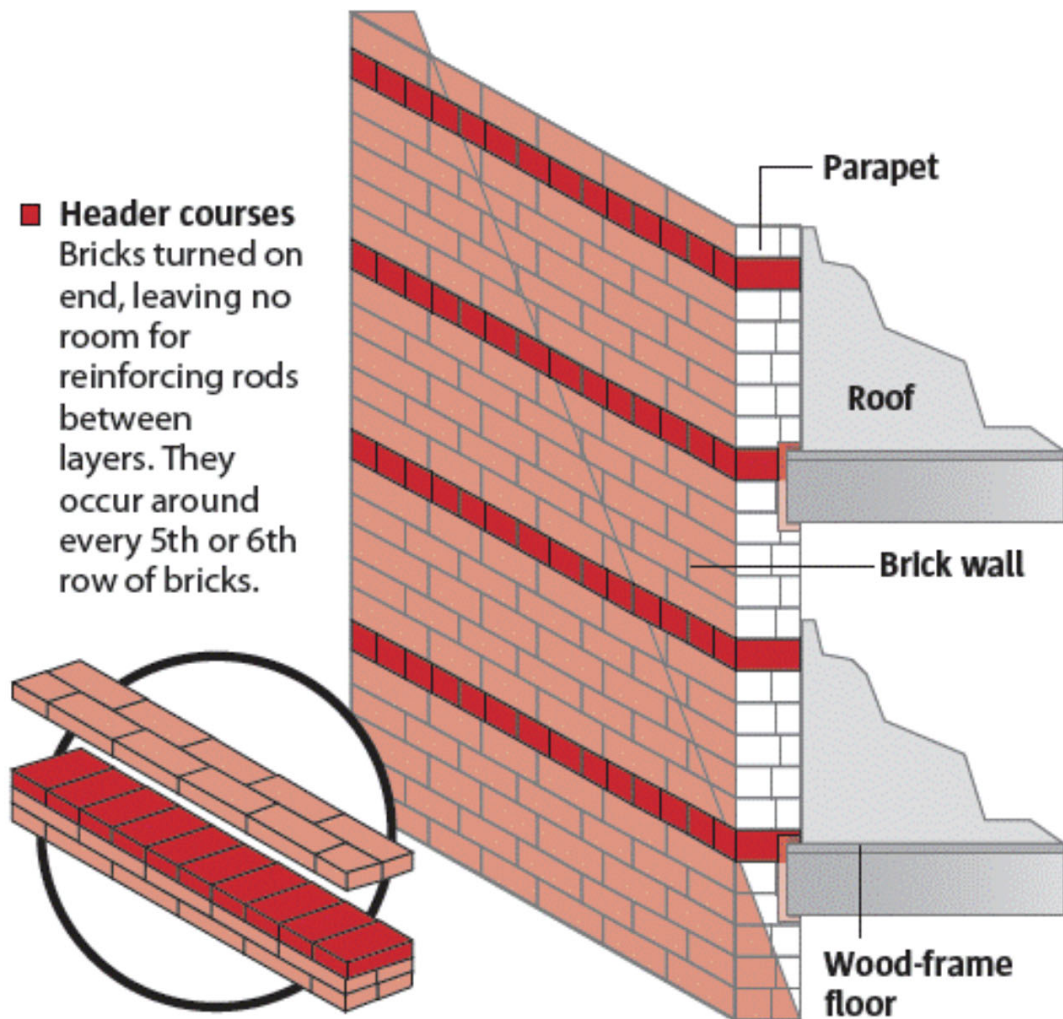
Photo from U.S. Geological Society Design Maps

# Washington Seismic Damage



# Vulnerable Building Construction

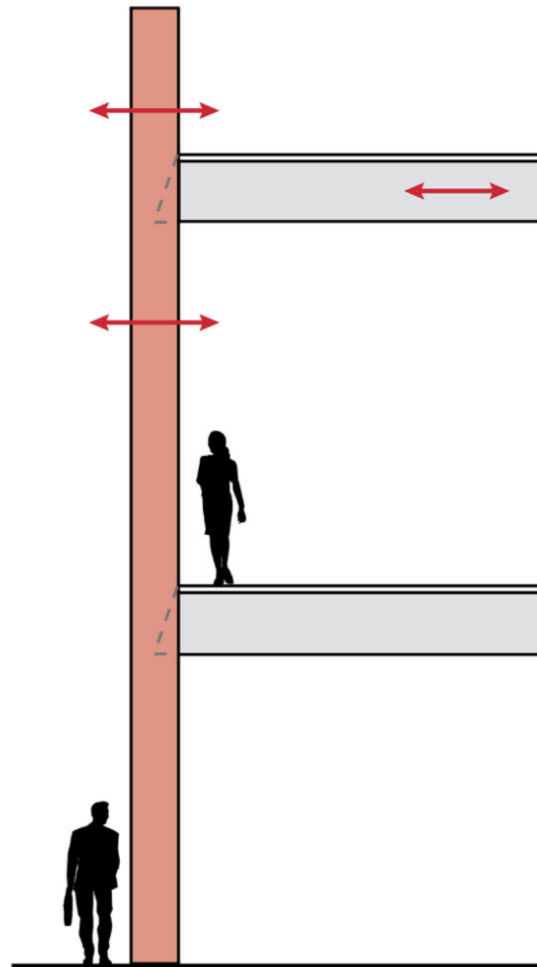
## *Unreinforced Masonry Buildings*



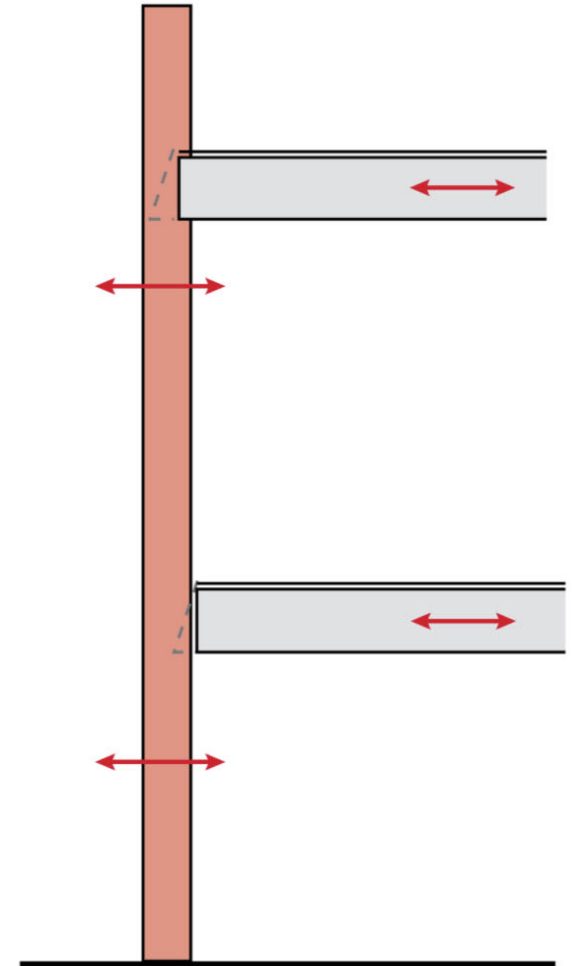
# Vulnerable Building Construction

## *Unreinforced Masonry Buildings*

Parapet breaks off



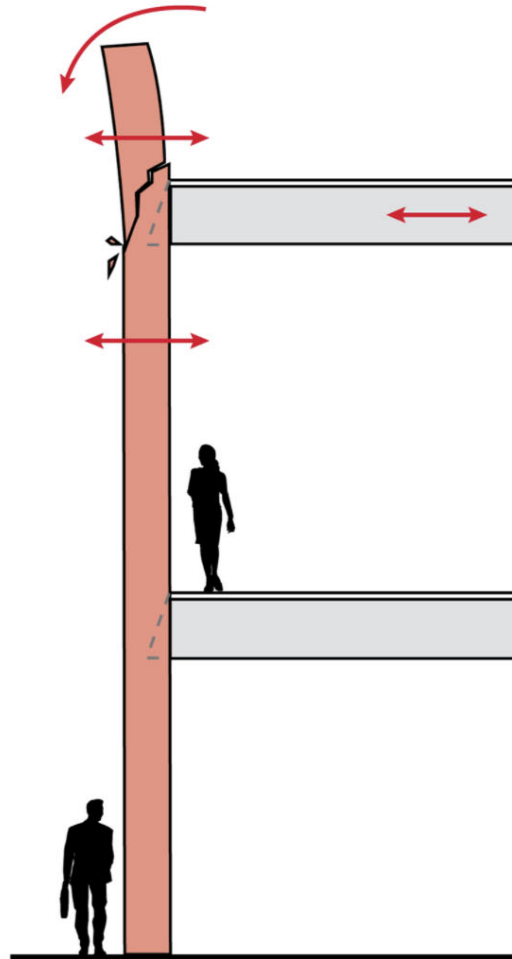
Building collapse



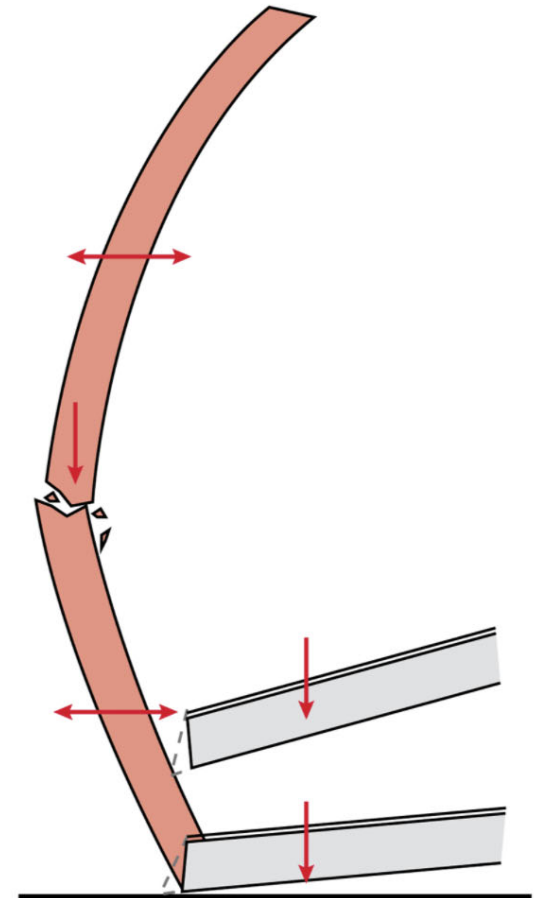
# Vulnerable Building Construction

## *Unreinforced Masonry Buildings*

Parapet breaks off



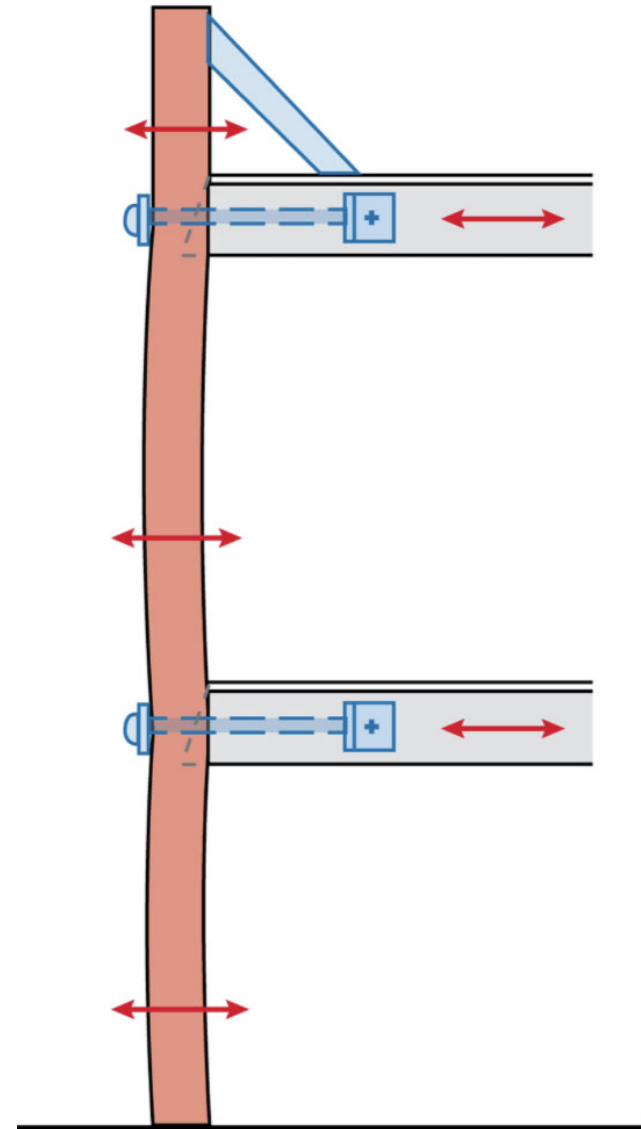
Building collapse



# Vulnerable Building Construction

## *Unreinforced Masonry Buildings*

- Provide mechanical connection between floors and walls
- Strengthen parapet and connect it back to the roof





# Vulnerable Building Construction

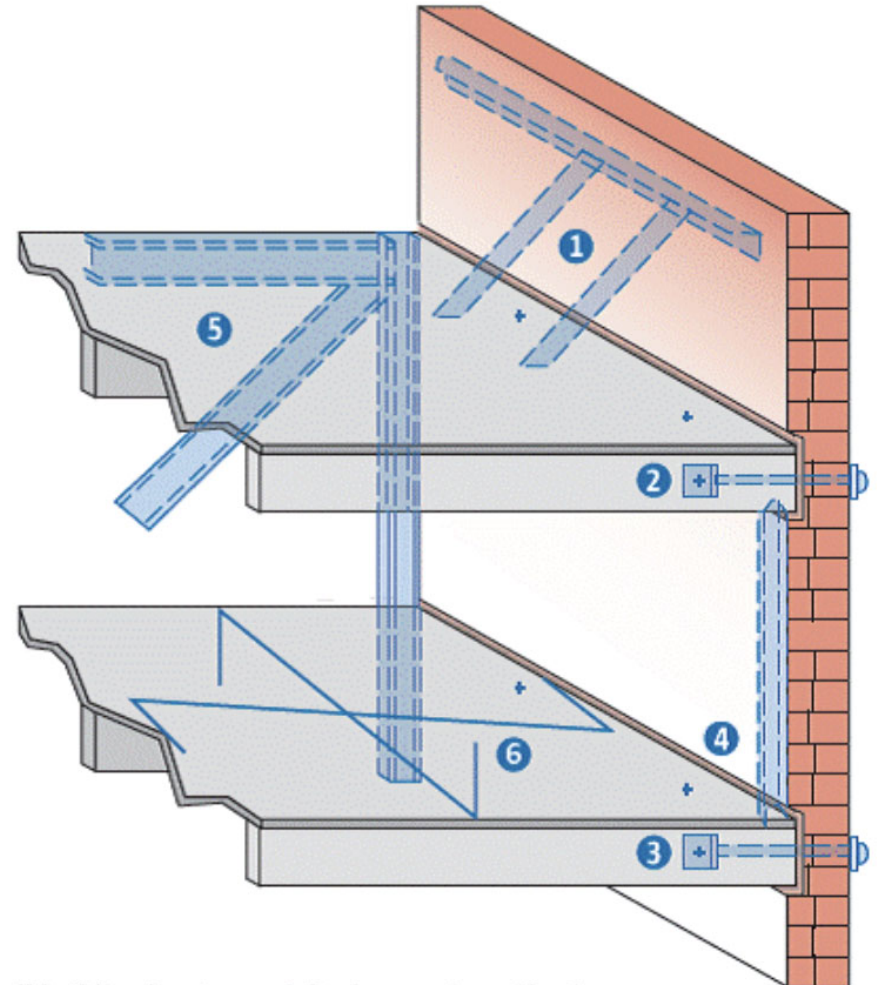
## *Unreinforced Masonry Buildings*

### REQUIRED

- 1 **Parapet bracing:** The portions of a wall that extend past the roof (parapet) need a diagonal bracing that is generally made of steel.
- 2 **Wall-to-roof diaphragm anchors:** Steel bolts horizontally secure the brick wall to the roof. Rosettes seen on the outside of a building can indicate that this retrofit has been done.
- 3 **Wall-to-floor diaphragm anchors:** Steel bolts tie the brick wall to the floors.

### SOMETIMES REQUIRED

- 4 **Out-of-plane wall bracing:** Steel beams that vertically connect the brick wall to the floors to keep the wall from bending.
- 5 **Overall building bracing\*:** Steel beams that increase a building's overall strength.
- 6 **Diaphragm strengthening\*:** Plywood sheathing that strengthens floors and roofs.



*Note\*: Overall building bracing and diaphragm strengthening are often important for buildings with large windowed shops on the first level.*



# Vulnerable Building Construction

## *Nonductile Concrete Buildings*

- Structures that contain brittle concrete elements (columns, beams, walls, and connections)
- Perform poorly during earthquakes due to the limited amount of provided reinforcing steel
- Usually built prior to 1980

# Vulnerable Building Construction

## *Nonductile Concrete Buildings*

Mexico City earthquake (1985)  
Northridge earthquake (1994)  
Christ Church earthquake (2011)  
Mexico City earthquake (2017)

Typical damage:

Soft story failure  
Severe column damage/failure



# Previous earthquakes & Public policy

1933 Long Beach Earthquake  
(California, USA)



**CA Field Act (1933)**  
**Division of State Architect**  
**(DSA)**

1960 Valdivia Earthquake  
(Chile)



**ONEMI**  
**(National office of**  
**emergency management)**

1960 Tokyo Earthquake  
(Japan)



**Disaster Prevention Day**  
**Seismic safety in schools**

2008 Wenchuan Earthquake  
(China)



**International Conference**  
**on School Safety**

2011 Tohoku Earthquake  
(Japan)



**OECD Tohoku School**

# Seismic Ordinances

Wood-frame soft-story structures

Wood-frame soft-story structures  
Non-ductile concrete structures



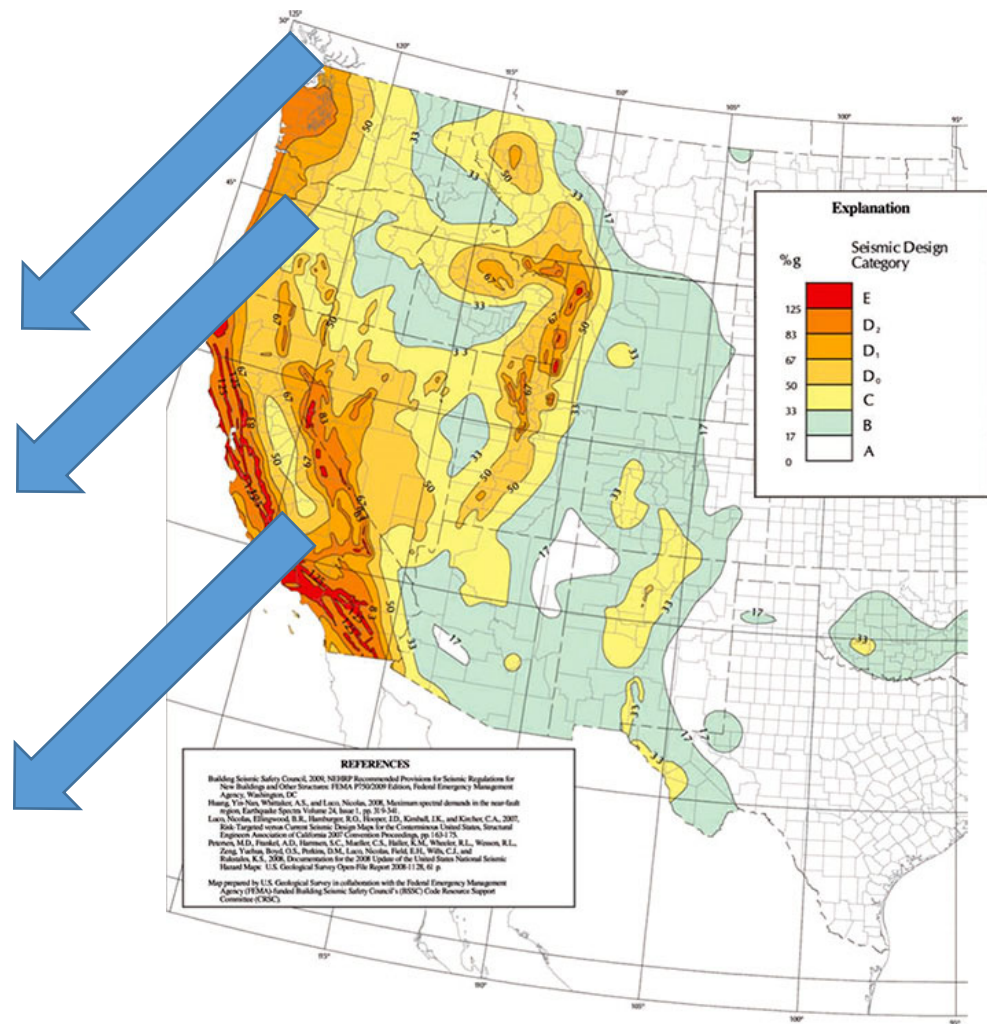


# West Coast Policy – Schools

BRITISH COLUMBIA (Canada)  
Seismic Mitigation Plan<sup>1</sup>

OREGON  
Quake Safe Schools  
Seismic Rehabilitation Grant Program<sup>2</sup>

CALIFORNIA  
1933 Field Act<sup>3</sup>



<sup>1</sup>Finn, W.D.L., Dexter, A. (2012). *Risk Management Plan for School Seismic Mitigation Program*. British Columbia Ministry of Education.

<sup>2</sup>IFA. (2007). *Oregon Seismic Rehabilitation Grant Program*. Oregon Infrastructure Finance Authority:

<http://www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab/>

<sup>3</sup>CSSC (February 2007), *The Field Act and Public School: Construction: A 2007 Perspective*, Publication #CSSC 2007:03, California Seismic Safety Commission

# Research at Oregon State University

*in collaboration with KPFF*

*Credit: Renee Engleson / Andre R. Barbosa /  
Reid Zimmerman*

**Contact Erica Fischer directly for more  
information**



**Thank you!**

***Questions?***