Building Codes - *Why they matter*

By:
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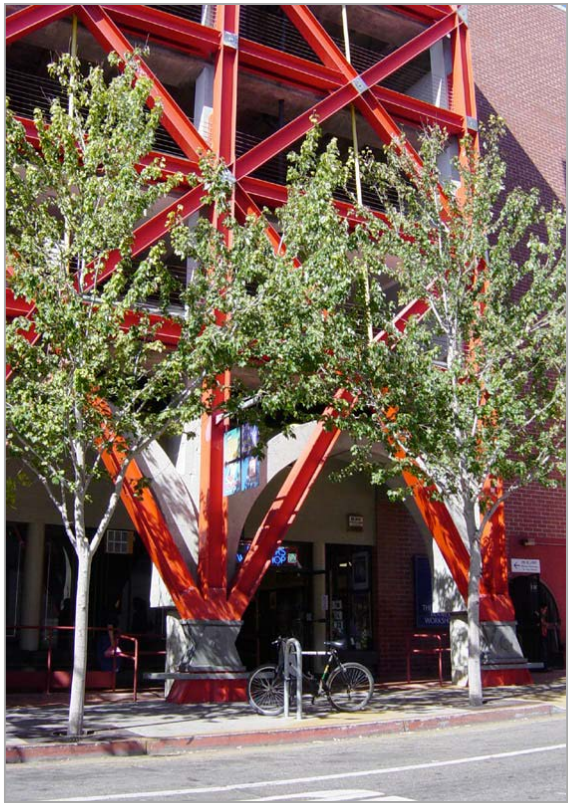
Developed under FEMA NETAP Program

Presentation Outline

- Building Code Purpose and History
- Code Adoption and Enforcement
- Earthquake Primer
  - Earthquake Hazards
  - Seismic Behavior Fundamentals
  - Common Seismic Vulnerabilities
- Benefits of Building Codes
- Resources



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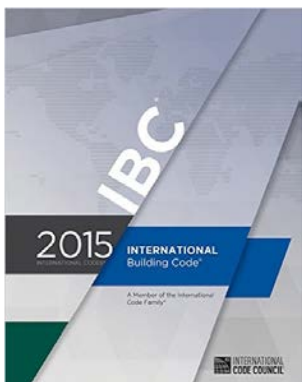
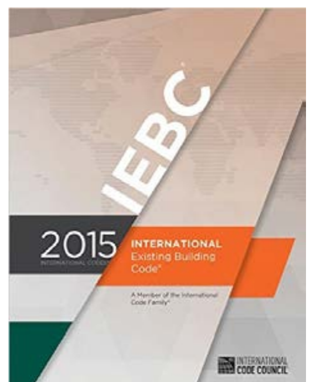
BUILDING CODE PURPOSE & HISTORY

What are Building Codes?

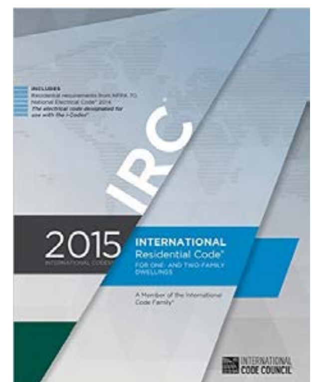
- Regulations governing the design, construction, alteration, and maintenance of structures
- Minimum requirements to safeguard the health, safety, and welfare of building occupants



INTERNATIONAL
Building Code



INTERNATIONAL
Existing Bldg. Code



INTERNATIONAL
Residential Code

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Purpose of Building Codes

"The purpose of this code is to establish the **MINIMUM** requirements to provide a **REASONABLE** level of safety, public health and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide a **REASONABLE** level of safety to fire fighters and emergency responders during emergency operations."

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Why are Building Codes Important?

- Building Codes:
  - Save lives
  - Improve disaster resilience
  - Enhance building stock
  - Reduce insurance premiums
- Codes are for life safety protection and not loss prevention
- Everyone benefits when money is saved and losses are avoided

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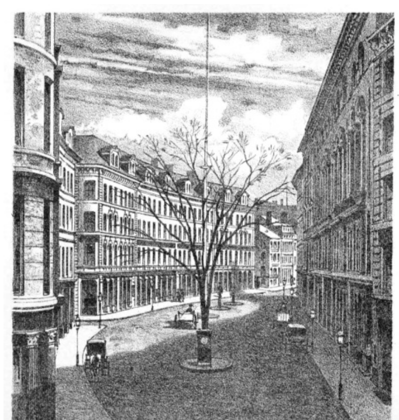
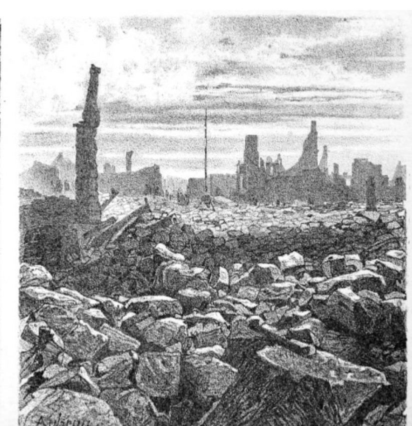
History of U.S. Building Codes

- Building Codes evolved over time largely in reaction to disasters and perceived threats (natural & man-made) lives and property
- Earliest building regulations addressed problems associated with dense urban construction (improved substandard housing and control rapid spread of fire)
- Building regulations in the U.S. date to the 17th century
  - Boston, Massachusetts (1872)
    Fire - wooden chimneys
    and thatched roofs outlawed



FRANKLIN STREET, LOOKING UP.



FRANKLIN STREET, LOOKING DOWN.

History of U.S. Building Codes

- Three model building code organizations formed between 1915 and 1940
- Each of these Building Codes was adopted largely in separate regions of the United States
  - Building Officials and Code Administration (BOCA): National Building Code
  - International Congress of Building Officials (ICBO): Uniform Building Code
  - Southern Building Code Congress International (SBCCI): Standard Building Code

History of U.S. Building Codes

- BOCA, ICBO, and SBCCI formed the International Code Council (ICC) in 1994
  - Developed one set of uniform standards to be applied throughout the United States
  - Referred to as the I-Codes
  - IBC-2000 was the first Building Code from the International Code Council
  - Most current I-Codes are the 2015 Editions

Code Development Process

- ICC International Codes have a 3-year update cycle
  - Updates are a result of research and experience
  - Changes go through democratic consensus process
- Code updates are incremental (every 3 years)
  - Controls costs associated with new requirements
- Open process that allows code change proposal submittals from any individual
- Balloting of proposed code changes is done by ICC members

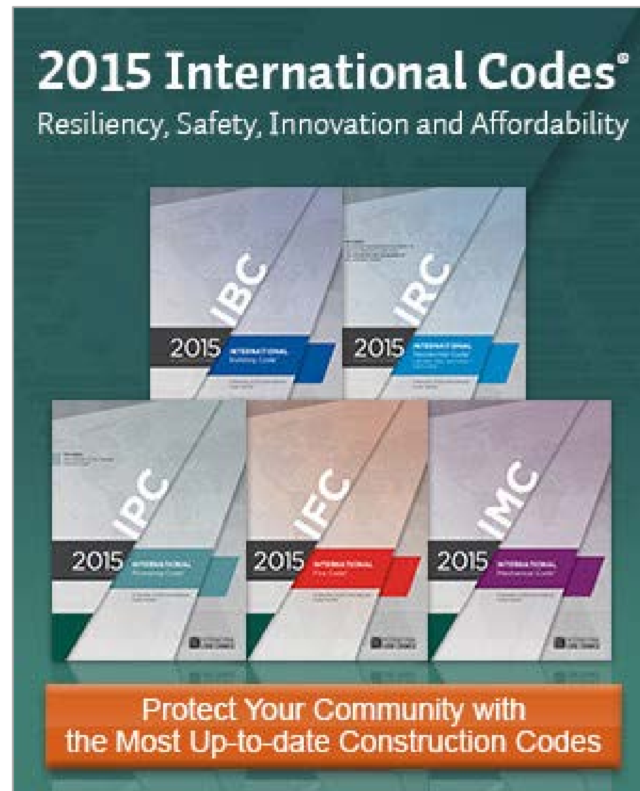
Code Development

- The International Code Council (ICC) develops codes in collaboration with:
  - Federal Emergency Management Agency
  - Other Federal, state, local, and private authorities
  - Professional organizations

CODE ADOPTION
& ENFORCEMENT

Code Adoption

- Rather than create and maintain their own codes, most States and local jurisdictions adopt the model building codes maintained by the International Code Council (ICC)
- ICC Publishes a variety of Codes:
  - Building: IBC, IRC, IEBC
  - MEFP: IMC, IFC, IPC
  - Green: IECC, IgCC
  - Other specialty codes: International Wildland-Urban Interface Code (WUI)



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Code Adoption

- Adoption of the model codes is uneven across the country and within individual States
  - Inconsistent adoption present even in areas with high exposure to natural hazards (earthquakes, hurricanes, tornadoes, floods, winter storms, etc.)
- Unless a community has adopted the latest model building code, new structures may not provide the current minimum level of protection
  - Human and economic costs of natural disasters will rise when latest regulations are not in place

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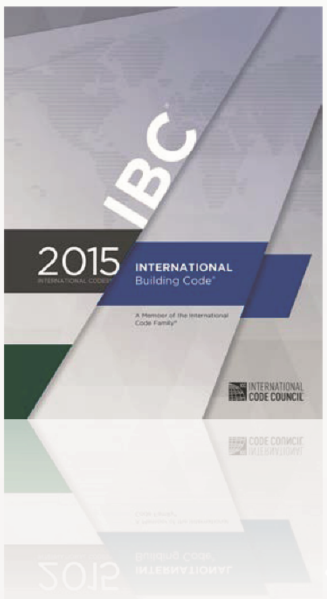
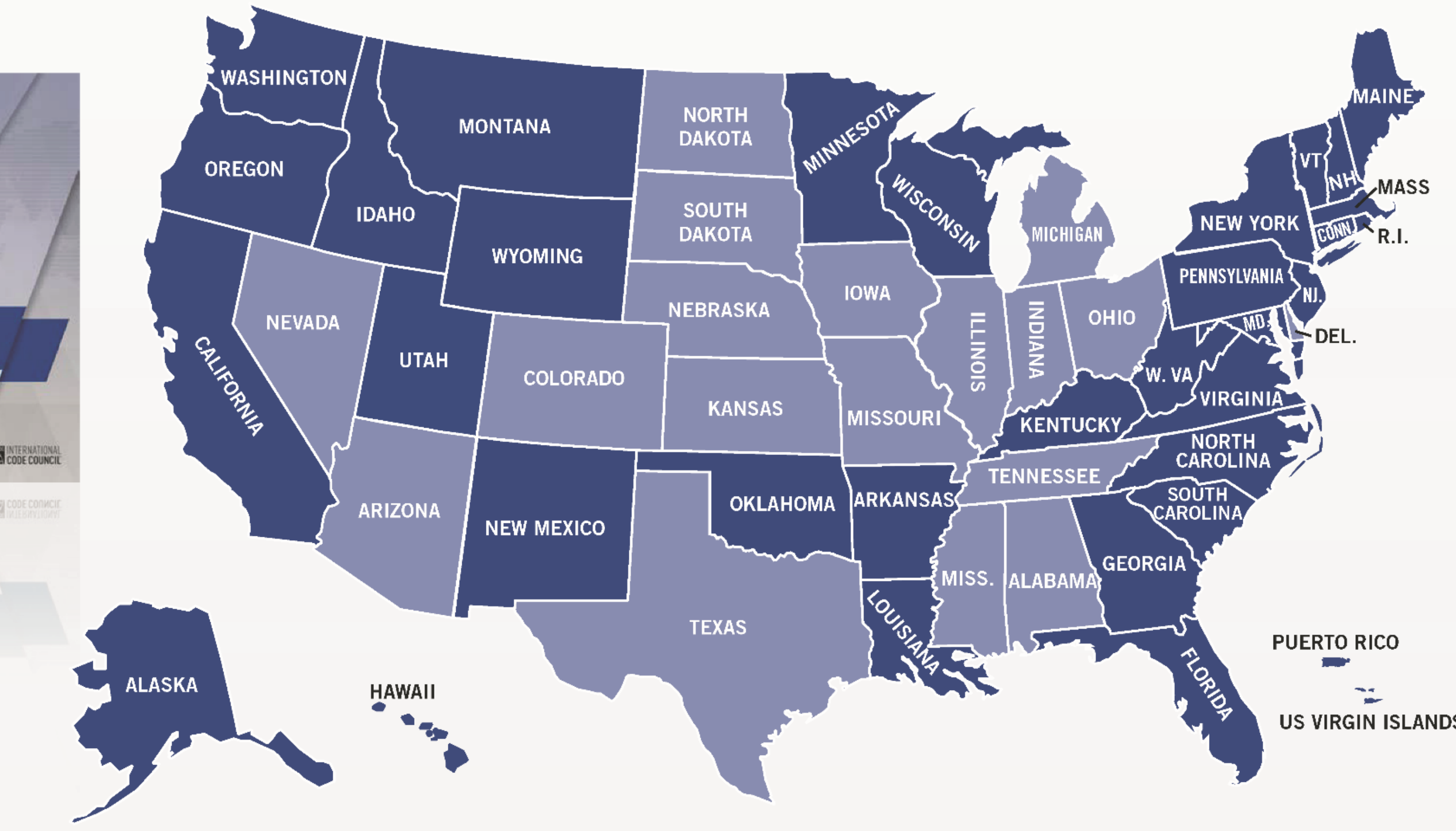
ICC
INTERNATIONAL CODE COUNCIL®

INTERNATIONAL BUILDING CODE
ADOPTION MAP

The IBC is in use or adopted in 50 states, the District of Columbia, the U.S. Virgin Islands, NYC, Guam and the Northern Marianas Islands.





IBC administered statewide

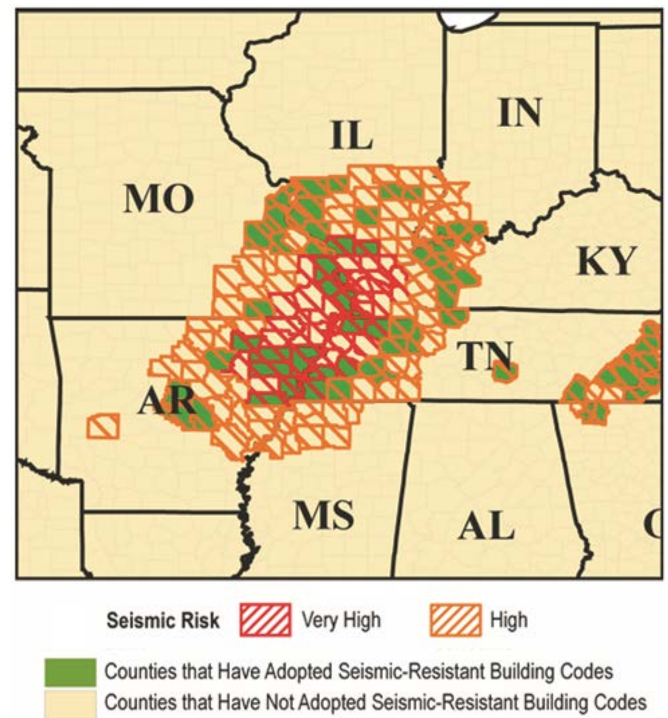
IBC administered at the state and/or local level

New Madrid Seismic Zone
I-Code Adoption (2000 or later)

- Jurisdictions in the NMSZ with High or Very High Seismic Risk that have adopted codes with Seismic-Resistance Code Provisions

State	High or Very High Seismic Risk	Seismic-Resistant Code Provisions	
		IBC	IRC
Arkansas	26	16	8
Illinois	45	31	3
Indiana	26	13	0
Kentucky	41	12	2
Mississippi	2	0	0
Missouri	97	82	4
Tennessee	75	37	16

BCEGS December 30, 2010 Data

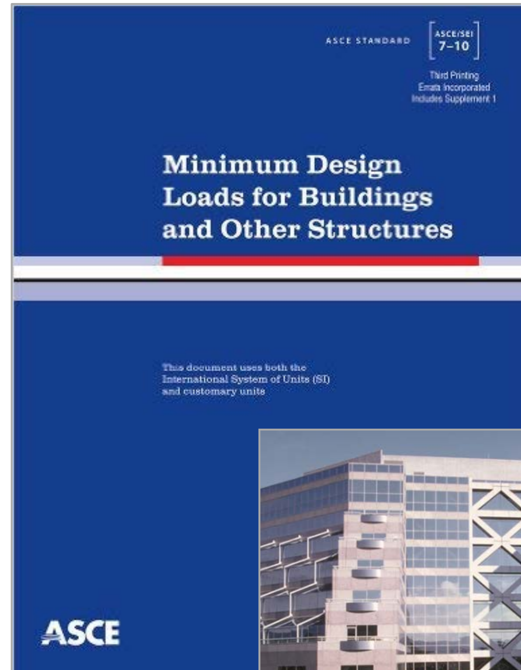


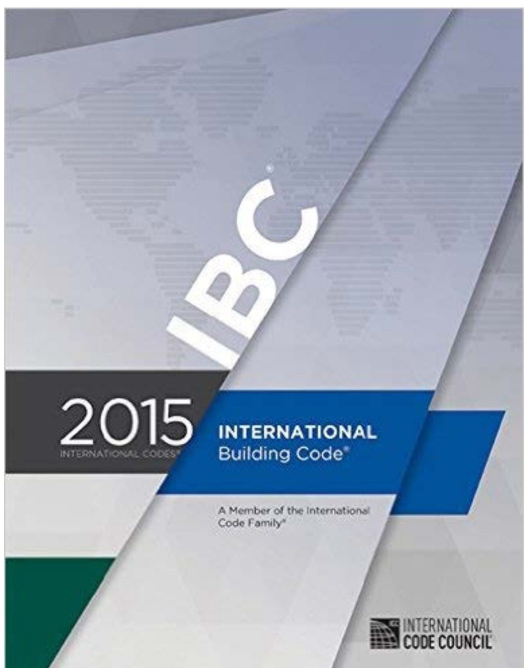
Seismic Code Adoption

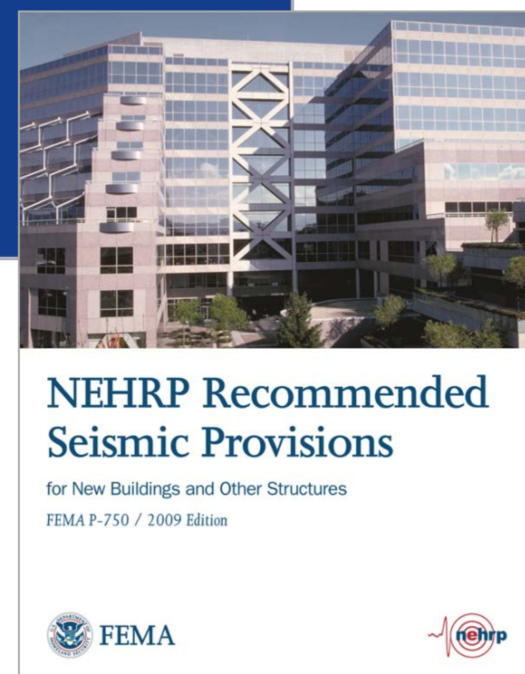
- Seismic provisions within the IBC, IRC, and IEBC represent the best available guidance on how structures should be designed and constructed to limit seismic risk
  - Adopt latest version of a model code in its entirety to be operating at the current standards
- In the past, some local governments viewed seismic sections of the model building codes as optional (adopted at local discretion)
- Seismic provisions are now fully integrated into the model building codes

Seismic Code Provision Incorporation

- NEHRP and ASCE 7 (consensus standards) are incorporated by reference into the IBC & IRC



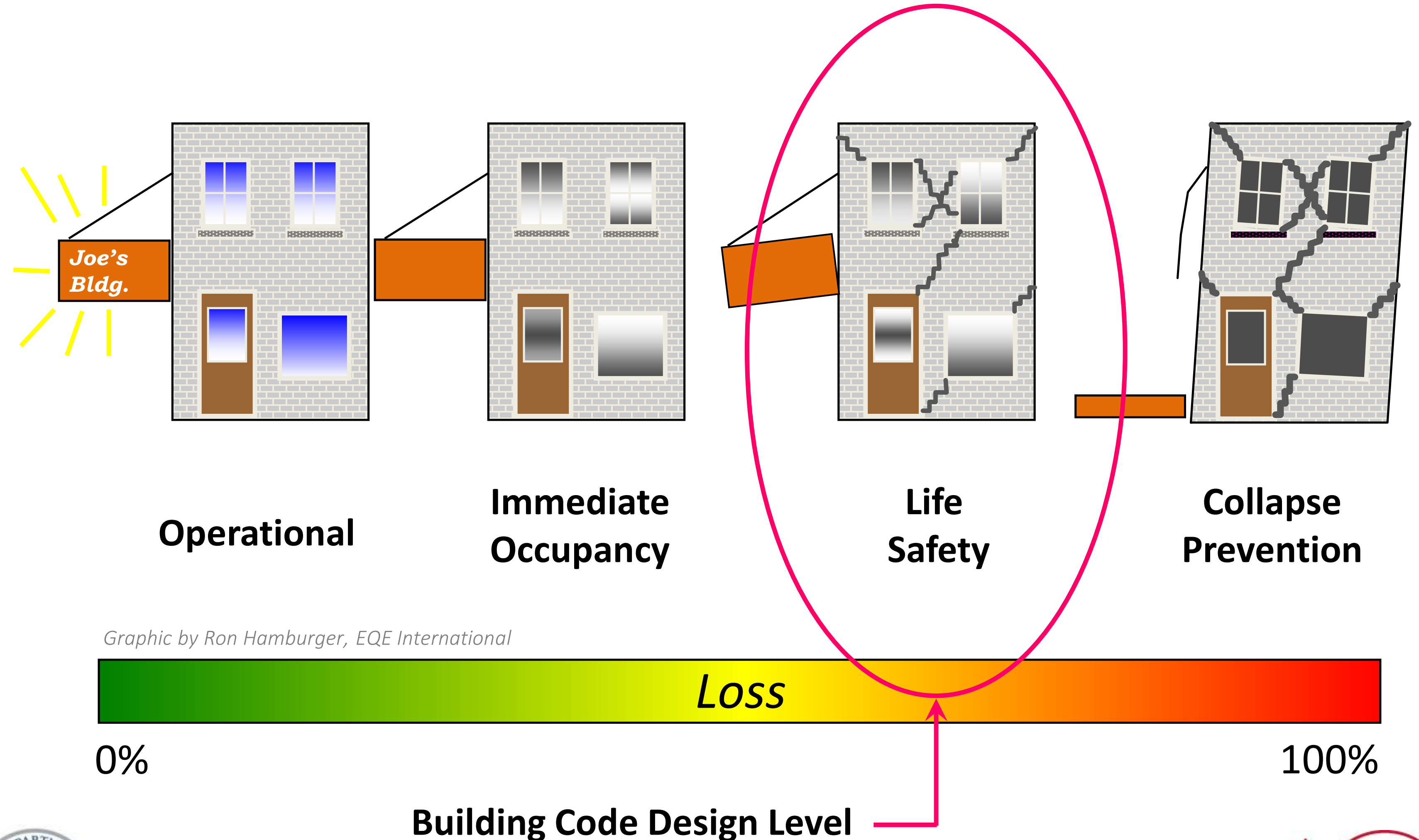




Seismic Code
Expected Building Performance

- Seismic design standards reflect balancing of the risks versus the cost of designing to withstand that risk
  - Design for appropriate sized event
  - Design for appropriate performance goal
- Primary focus is on preventing collapse and protecting life safety
  - Buildings are not earthquake-proof
  - Damage will occur

Seismic Performance Levels



Graphic by Ron Hamburger, EQE International

Code Enforcement

- Adopting the latest Building Code is only part of the solution
- Codes must be effectively enforced to ensure that buildings and their occupants benefit from the advances in the Building Code
- Code enforcement is typically the responsibility of local government officials who review design plans, inspect construction, and issue the building and occupancy permits

Code Enforcement

- State Farm Insurance Co. contracted with SBCCI to evaluate code compliance in 12 randomly selected coastal communities in 1991
- Study findings:
  - Half of the communities were not enforcing their own code standards for wind resistance
  - Inspectors and reviewers had little or no training in wind-resistant construction
  - General lack of enforcement of adequate connections for windows, doors, and mechanical equipment

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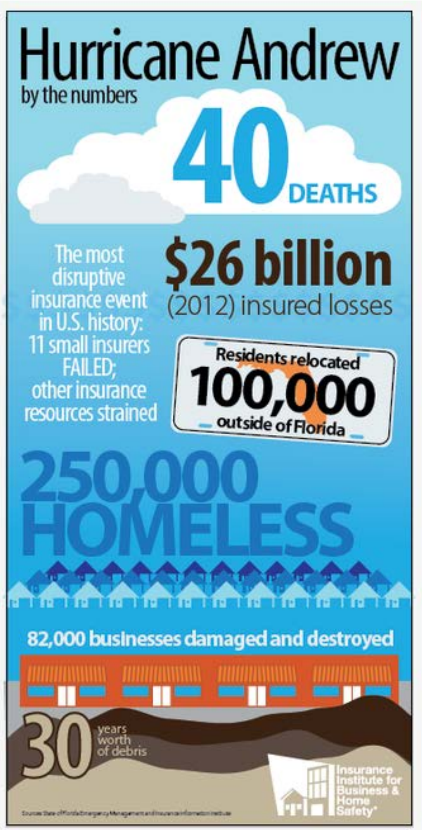
Code Enforcement

- Significant weakness in code enforcement exposed following Hurricane Andrew
  - Reports by Dade County grand jury and the Federal Insurance Administration concluded a substantial portion of storm damage was attributable to lack of enforcement of the South Florida Building Code
  - Estimated that at least 25% of the $26 billion in insured losses were from construction that failed to meet code



Elements of Code Enforcement

- Keep the Code provisions up to date
- Ensure that builders apply for building permits
- Qualified plan reviewers
  - Code organizations offer certification programs
- Ensure that construction proceeds according to the approved plans
- Qualified building inspectors
  - Certification available through code organizations

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What about Older Buildings?

- Code requirements for existing buildings are typically those in effect when the structure was designed and constructed except in certain circumstances (significant renovation, change in use) that trigger current IBC or IEBC code provisions
- Many older buildings are not well-protected against earthquake damage
  - Seismic retrofit is voluntary in most jurisdictions
  - Some local governments in high-hazard areas have enacted ordinances mandating owners evaluate and retrofit older vulnerable buildings (URMs, soft-story wood frame construction, non-ductile concrete frame)

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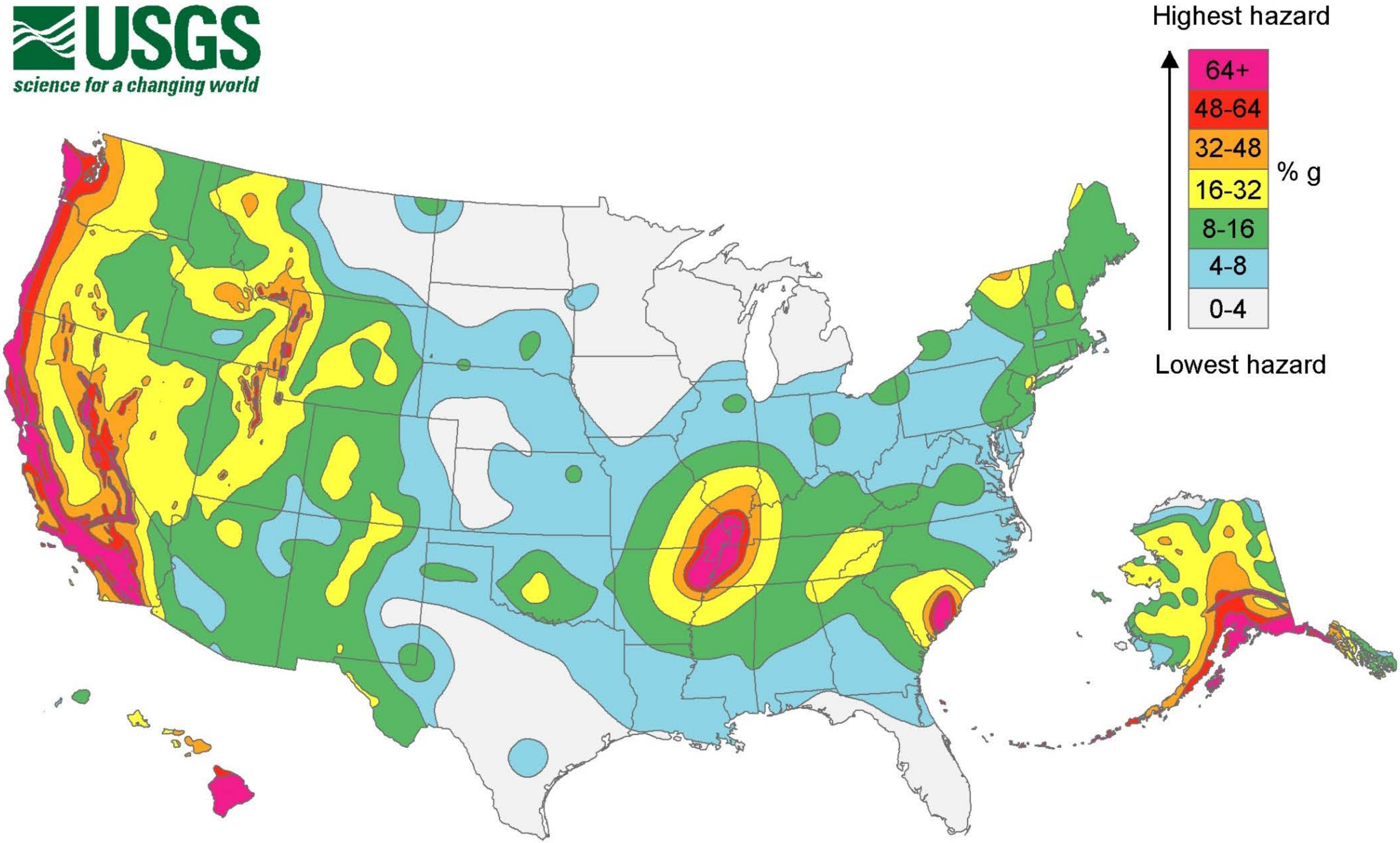
SEISMIC HAZARDS



Seismic Hazard Map

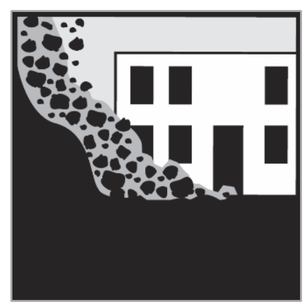
PGA, 2% in 50 yr probability of exceedance

from Department of Interior, US Geological Survey, Open-File Report 2008-1128

Earthquake Hazards

- Ground Shaking
- Surface Faulting
- Liquefaction
- Landslide
- Tsunami
- Man-made Consequences
  - Fire following earthquake
  - Hazardous chemical spills
  - Nuclear plant radioactivity
  - Flooding (levee break)



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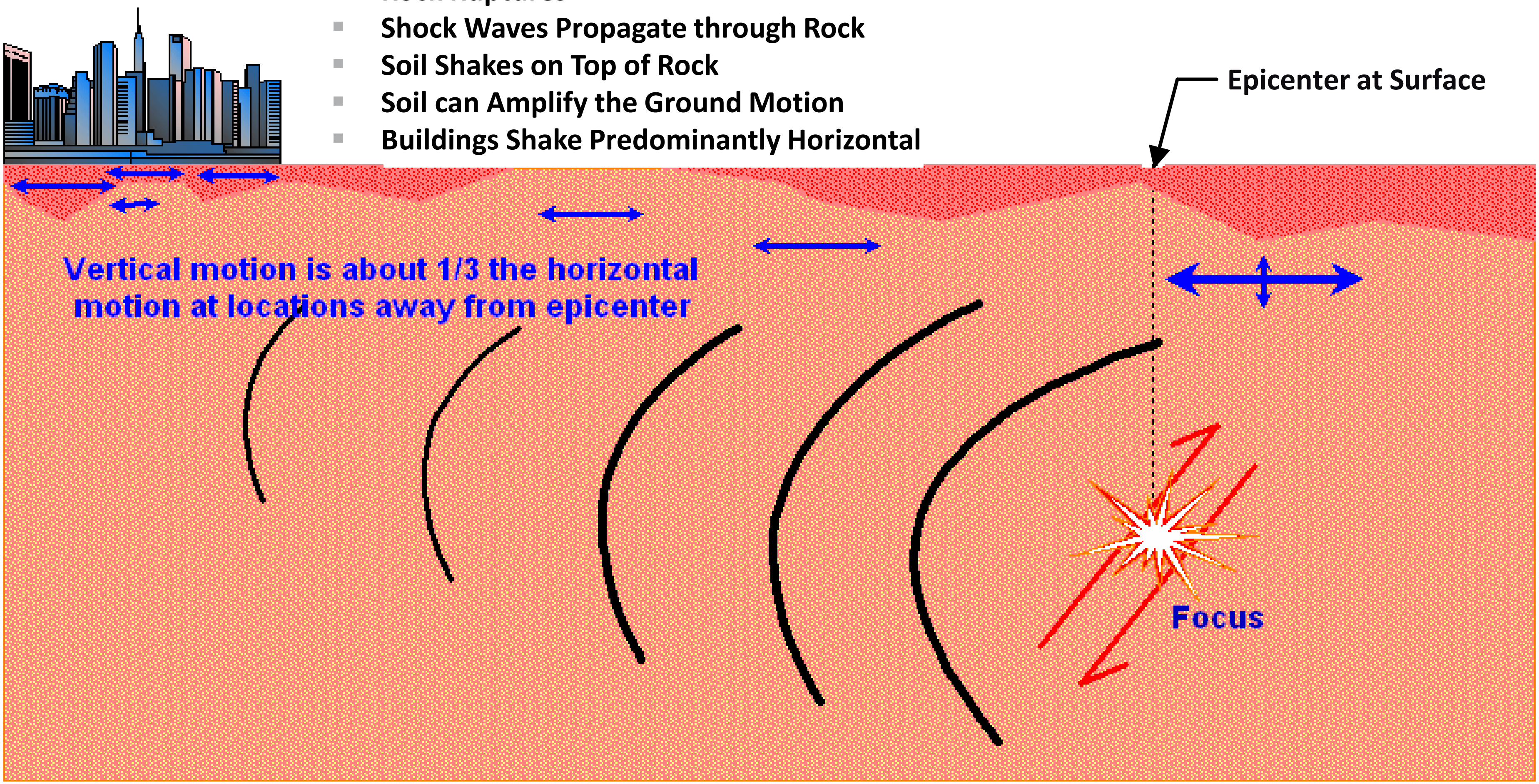
Ground Shaking

- Rock Ruptures
- Shock Waves Propagate through Rock
- Soil Shakes on Top of Rock
- Soil can Amplify the Ground Motion
- Buildings Shake Predominantly Horizontal



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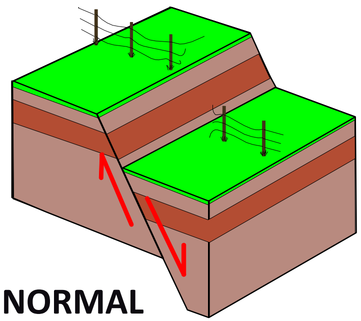
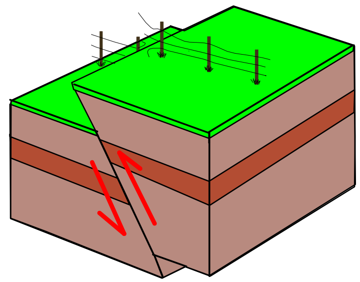
Surface Fault Rupture

DIP SLIP FAULTS

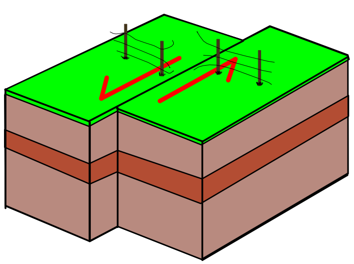


NORMAL

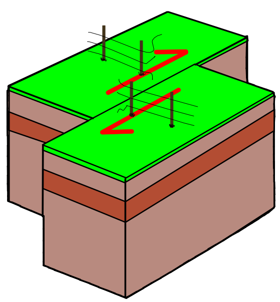


REVERSE

STRIKE SLIP FAULTS



LEFT LATERAL



RIGHT LATERAL

Kuangfu Junior High Track, 1999 Chi-Chi Earthquake
Photo by Robert Yeats, Courtesy of Oregon State University

Earthquake Trail, Point Reyes National Seashore
Photo by Betsy Malloy, 2008

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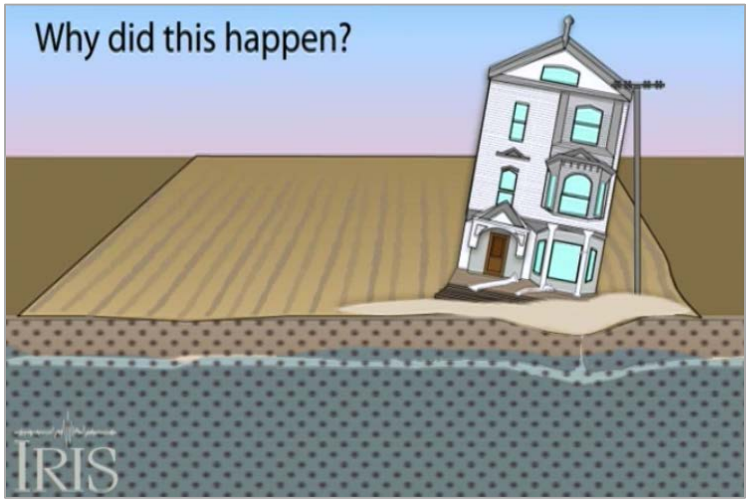
Liquefaction



Earthquake waves cause water pressure to increase in the sediment.

Sand grains lose contact with each other leading to loss of strength and liquid-like behavior.

Photo by G.K. Gilbert, Courtesy of the US Geological Survey

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Landslide

Government Hill Elementary, Anchorage, Alaska - 1964
Courtesy of Univ. of Alaska Anchorage, Special Collections

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Tsunami

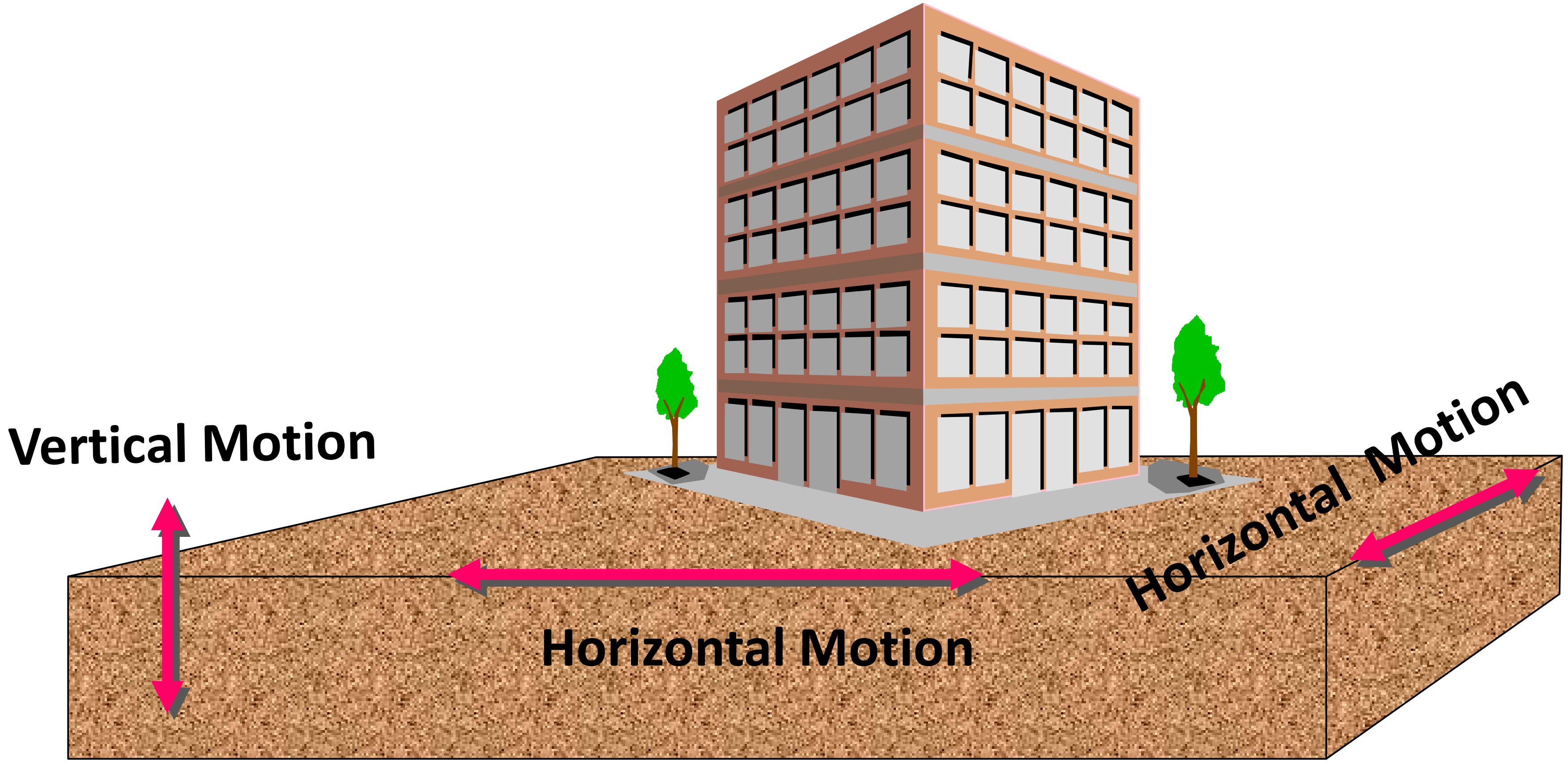
Great Sendai Earthquake, Japan - 2011
Photo by Associated Press via New York Times

Man-Made Hazards

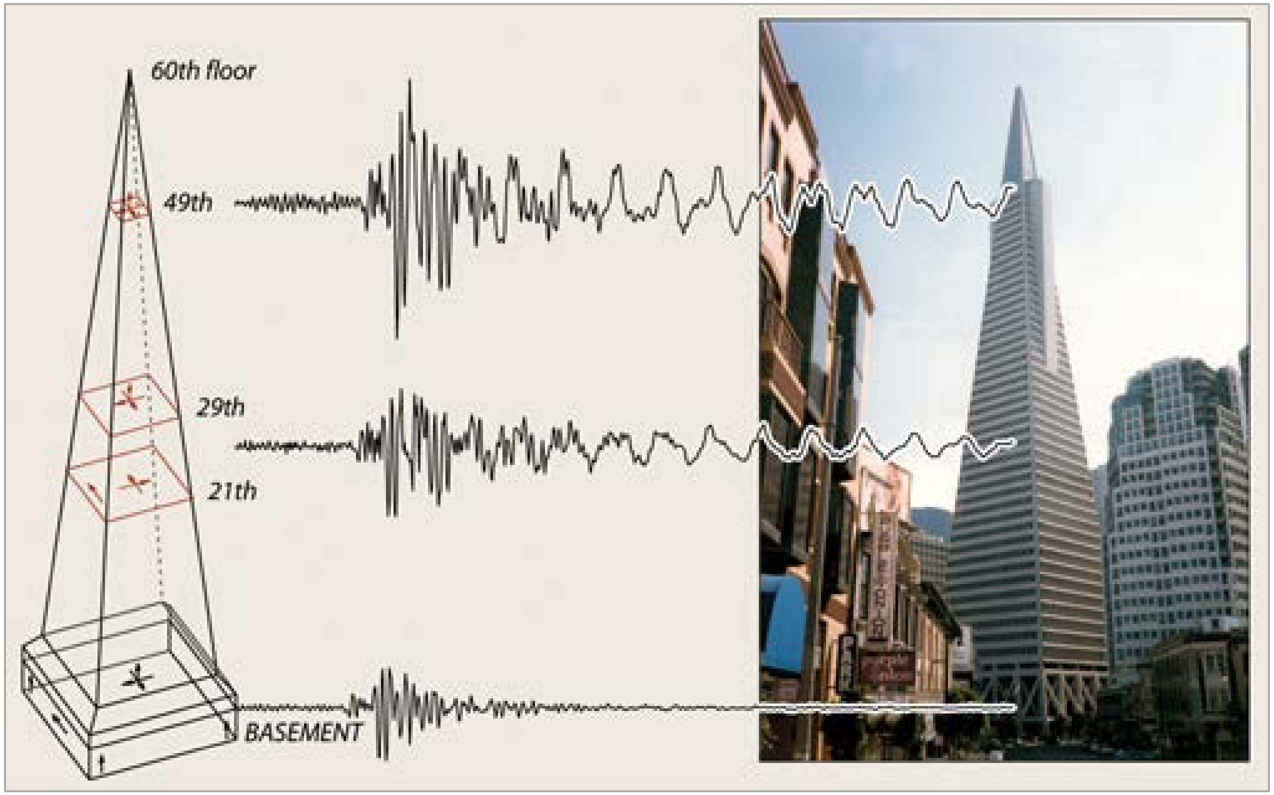
Cosmo Oil Refinery, Photo by Reuters

SEISMIC BEHAVIOR FUNDAMENTALS

Building Response to Earthquakes



Earthquake Forces



Transamerica Tower, San Francisco, California
Recorded during the 1989 Loma Prieta Earthquake

Shaking is amplified over the height of the structure

Earthquake Performance Indicators
Structural Irregularities

- Building vintage can affect building performance
  - Old buildings – strong and brittle
  - New buildings – ductile & ability to withstand high forces without collapse
- Building configuration can affect building damage
- Presence of irregularities is a general indicator of increased damage (particularly in older structures)
  - Vertical irregularity
  - Plan irregularity
  - Closely spaced structures (pounding)

Vertical Irregularity

Photo from FEMA P-154

Photo courtesy of the Earthquake Engineering Research Institute

Photo by Schmidt Hammer Lassen Architects

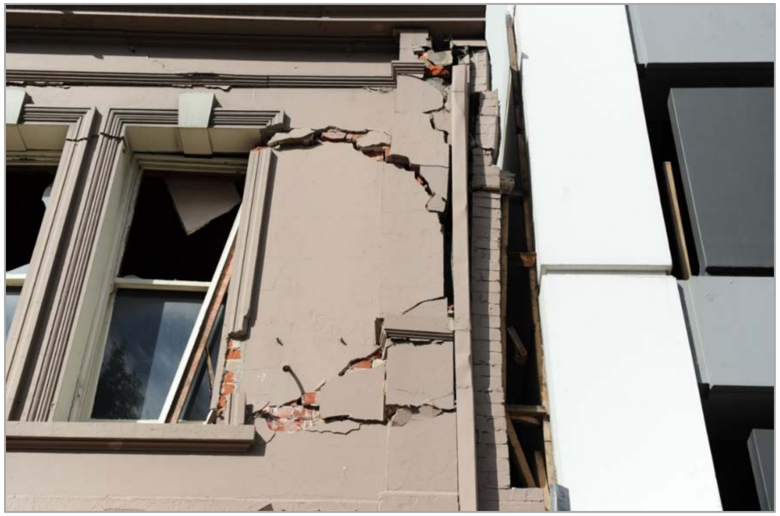
Plan Irregularity

Photo by Wiss, Janney, Elstner Associates, Inc.

Photo by Schmidt Hammer Lassen Architects

Photo by Thom Brajkovich, Paragon Architects

Closely Spaced Buildings (Pounding)



(T & B) Photos by Dave Swanson, Reid Middleton Structural Group

Photo by CCS Group, Inc.

EXAMPLES OF SEISMIC VULNERABILITIES

Unreinforced Masonry Buildings

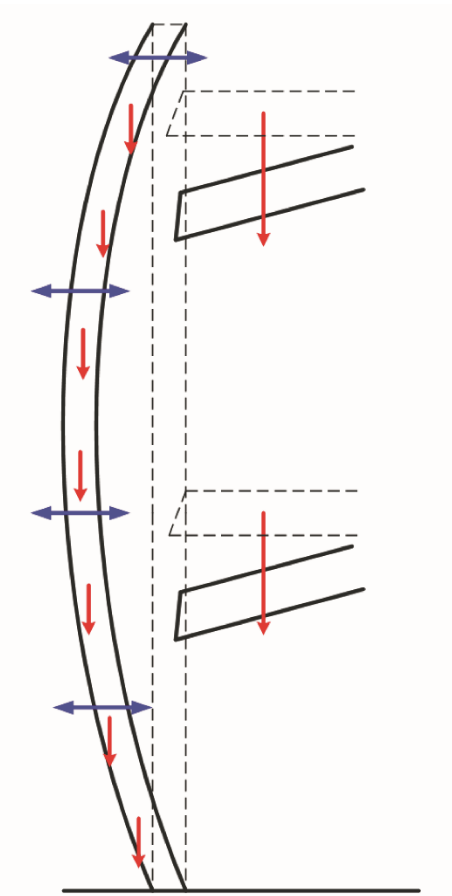


Photo by Dave Swanson, Reid Middleton Structural Group

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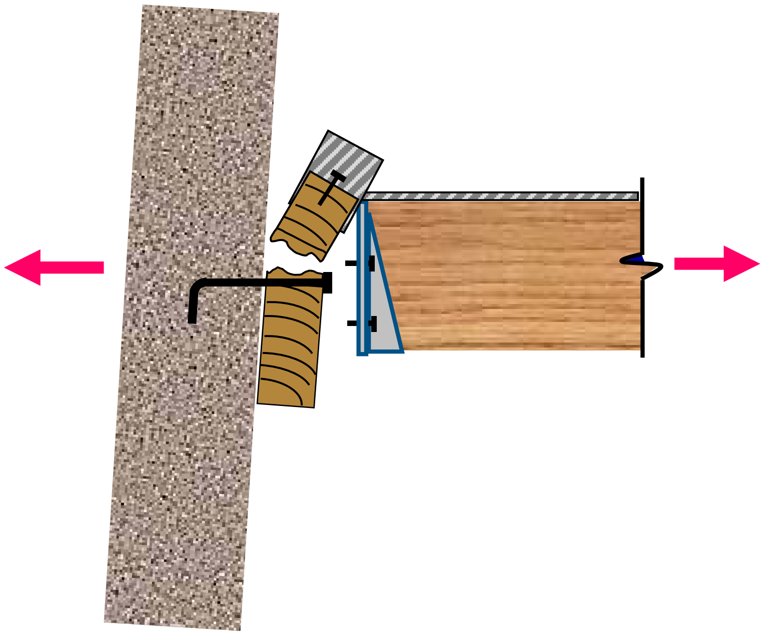
Tilt-up Concrete



Cross-grain ledger failure at tilt-up panel wall connection

Stiffness and Strength Deficiencies

Photo by J.K. Nakata, USGS

Photo by Bay Area Retrofit

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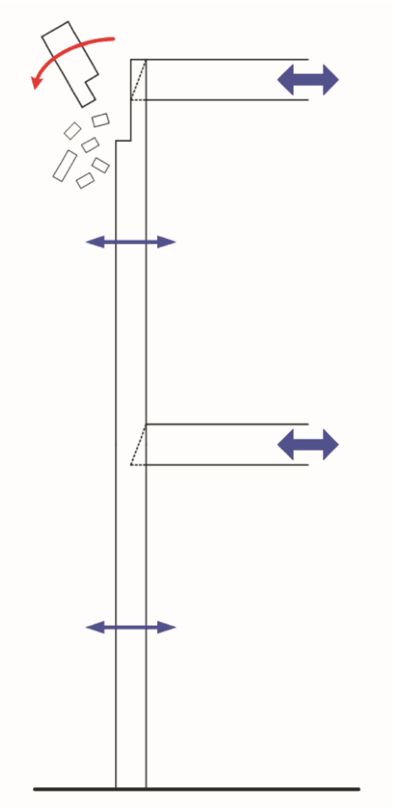
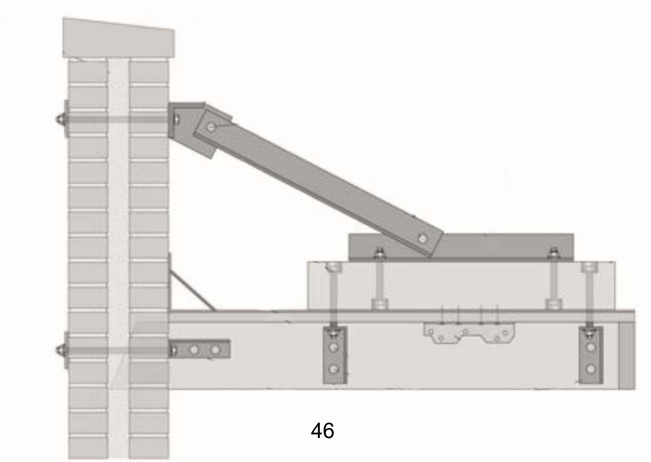
Nonstructural Deficiencies

URM Parapets

Photo by Laura Anthony, Bay City News
South Napa Earthquake, Aug. 2014 (M6.0)





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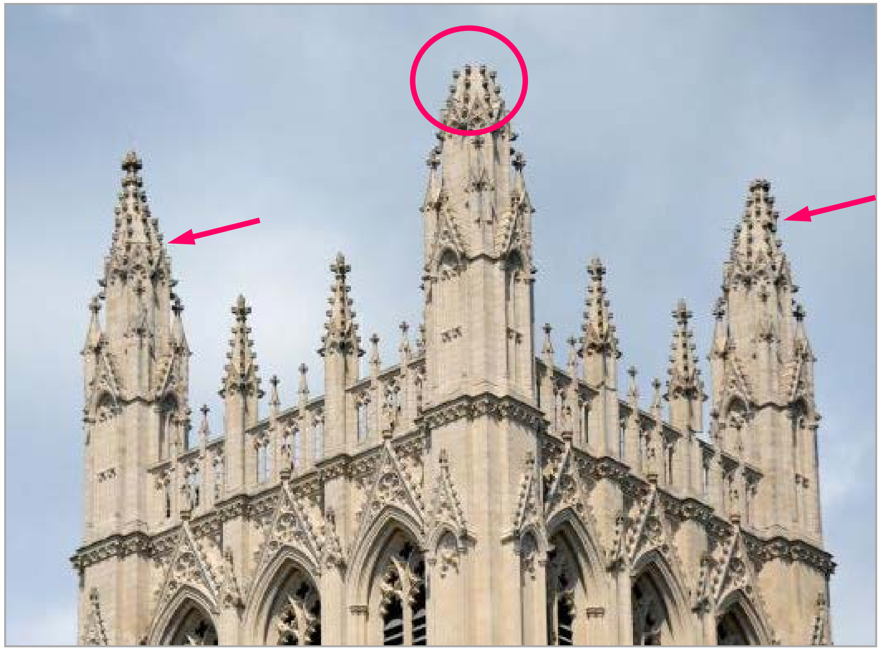
Masonry Chimneys

Photo from Element Roofing, 2010 Canterbury Earthquake, M7.1

Photo from Virginia Department of Mines
2011 Virginia Earthquake, M5.8

Washington National Cathedral



- Damaged by M5.8 Virginia Earthquake in Aug. 2011
- Damaged spires – toppled and dislodged blocks
- Angels and other statues fell both inside out and outside

Photo by J. Scott Applewhite, Associated Press

Falling debris hazards
Life Safety threat to persons evacuating the Cathedral

BENEFITS OF BUILDING CODES

Codes are living documents that evolve over time to reflect advances in technology, scientific research, and lessons learned

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Great Chicago Fire (1871)

- Dense wood construction
- Fire destroyed 3.3 sq. miles
- 100,000 left homeless
- Code Change:
  - Fire-resistant materials required for the construction of future downtown buildings
- Pressure from Insurers led to more stringent regulations and more thorough safety inspections

Long Beach Earthquake (1933, M6.4)

- School buildings suffered disproportionate damage
  - 230 school buildings destroyed, suffered major damage, or unsafe to occupy
- Heavy damage to unreinforced masonry buildings
- Reinforced concrete buildings sustained less damage

Lowell Elementary, Dominguez Hills Archives, California State University

John Muir School, Photo by W.L. Huber, USGS

Stanford School, J.B. Macelwane archives, St. Louis Univ.

Long Beach Earthquake

- Encouraged code adoption:
  - Recognizing moderate earthquakes would recur, multiple local governments in Southern California adopted seismic regulations
- Field Act
  - Mandates public schools designed for seismic forces
  - Design professionals qualified by state registration
  - Independent plan review and inspection
  - Design professional, contractor, and inspector verify that building constructed according to the approved plans

Northridge Earthquake (1994, M6.7)

- Connection failures in structures thought to be ductile
  - Damage not anticipated by engineering community
- Fractures occurred in steel moment-frame buildings
  - Observed in 1960s to 1990s structures and at sites that experienced moderate ground shaking
  - Low and midrise structures
- Structures initially appeared undamaged
  - Little associated architectural damage
  - Damage concealed by fireproofing
- Concern that similar, undiscovered damage in other buildings affected by past earthquakes

Modern seismic codes are effective, improving life safety protection and reducing property losses

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South Napa, California Earthquake

- August 24, 2014, M6.0
- 2 killed, 300 injured
- Moderate to severe damage to > 2,000 buildings
- Few building collapses
- California Seismic Safety Commission PEER Study (*CSSC Publication 16-03, June 2016*)
  - City of Napa's URM retrofit program was found to be successful in reducing damage and risk to life safety.
  - Modern buildings generally met or exceeded code performance standards.

Photo by Kelly Cobeen

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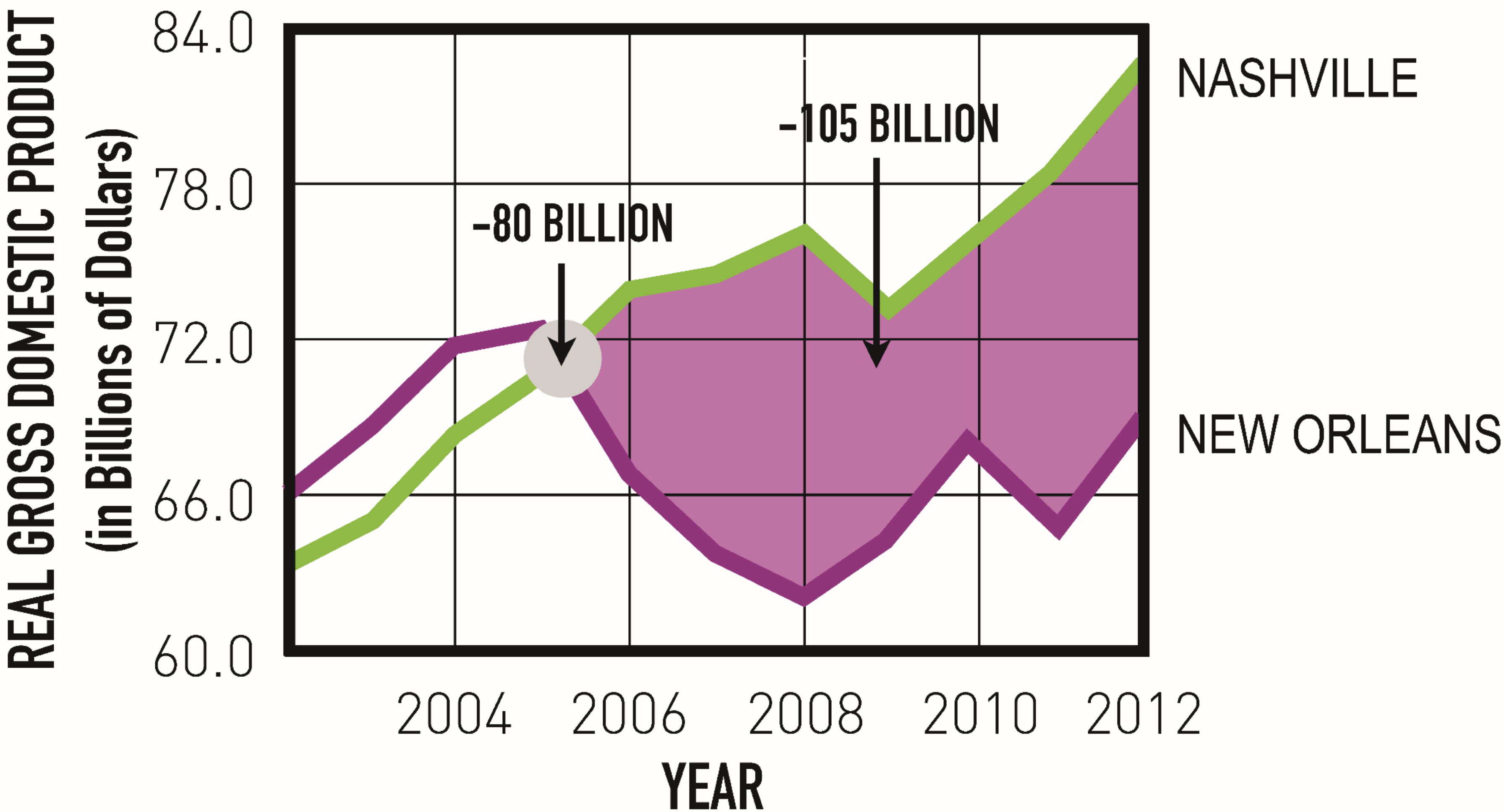
Enhanced Community Resilience

Resiliency Revolution

- Strong link between Building Code adoption and enforcement and mitigating catastrophic losses
- Prospect of lessening catastrophe-related damage and ultimately lowering insurance costs is incentive for communities to enforce building codes
- Preventing and mitigating property losses enables communities to rebound quickly

Increased Resilience = Less Damage = Lower Insured Losses = Lower Rates

NEW ORLEANS VS NASHVILLE ECONOMIC GROWTH



Graphic by Dr. Lucy Jones, USGS

Resiliency Examples

- 100 Resilient Cities initiative

*"Helping **cities** around the world become more resilient to the physical, social, and economic **challenges** that are a growing part of the 21st century."*

- Los Angeles – Resilience by Design
  - 1st Recommendation – Strengthen Our Buildings
- Resilient San Francisco – Stronger Today, Stronger Tomorrow

Resiliency Example – Los Angeles

Los Angeles – *Resilience by Design*

- Recommendation – Strengthen Our Buildings
  - Assess and Retrofit Pre-1980 Soft Story and Concrete Buildings
  - Implement a Seismic Safety Rating System
  - Create a Back to Business Program
  - Mandatory Retrofit of Buildings that are Excessively Damaged in Earthquakes
- Fortify our Water System
- Enhance Reliable Telecommunications

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Recovery time can be reduced by building to the current codes and retrofitting older buildings to improve performance

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Seismic Strengthening
Anheuser-Busch Van Nuys Brewery

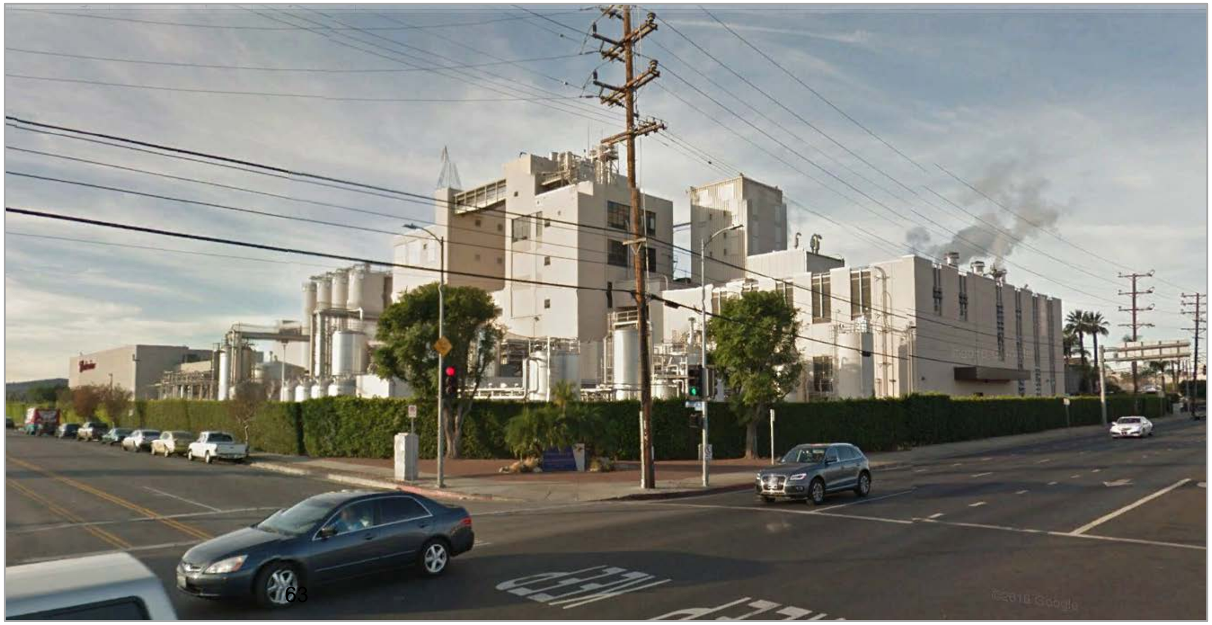
- Seismic strengthening of Brewery buildings, tanks, & nonstructural components in the mid-1980s
- Retrofit cost < 1% of total replacement value
- Retrofit tested by the 1994 Northridge earthquake

Northridge EQ Outcome:

Mitigation was effective

Strengthening measures performed well

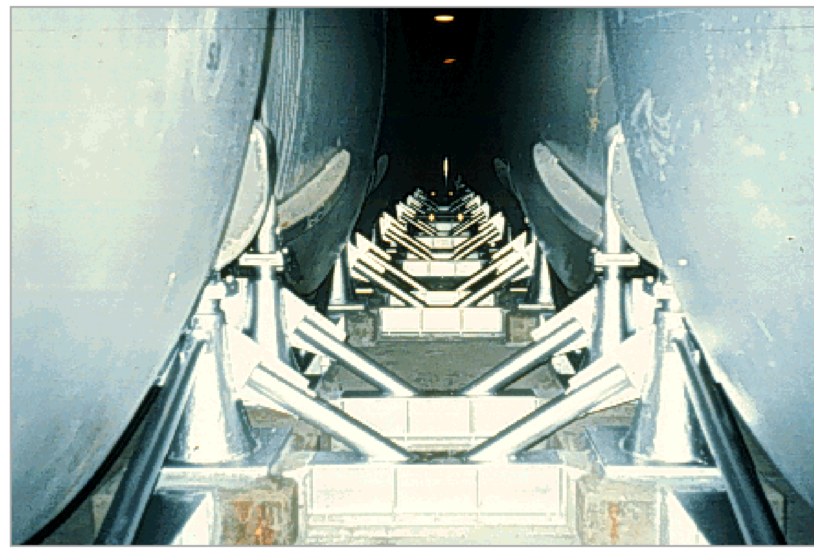
Damage to low-risk buildings that weren't strengthened



Seismic Strengthening
Anheuser-Busch Van Nuys Brewery

- Fermentation Tanks
  - Bracing added to tank supports
  - Tanks were not damaged

Hakutsuru Sake Brewery, Kobe



After Retrofit

Seismic Strengthening
Anheuser-Busch Van Nuys Brewery

- A-B estimated that total loss would have been in the range of $750 million to $1 billion
  - $350 million in direct property damage
  - $400 million in business interruption losses
  - Potential loss of market share due to lost production time (25% capacity for 6 to 18 months)
- Retrofit cost was $10 million
- Benefit-Cost Ratio: 75 (>>1)

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State of Oregon
Seismic Strengthening Grant Program

- 2013-2015 State Budget included $30 million for seismic strengthening
  - 22 schools retrofitted (8,600 children protected)
  - 18 emergency response facilities retrofitted
- 2015-2017 State Budget includes $175 million for seismic improvements

McLoughlin High School Gym
$650,000 seismic grant

Photo by Andy Giegerich, Portland Business Journal

Richmond Elementary
$1.5 million seismic grant

Photo by Danielle Peterson, Statesmen Journal

SUMMARY

Summary

- Building codes are effective, inexpensive and a good investment for the future of our communities
  - Most important factor in reducing community risk is adoption & enforcement of up-to-date building codes
- Key factors to success:
  - Adopt modern model building codes
  - Establish strong and efficient system of code enforcement
  - Maintain the system with a well-trained, professional workforce

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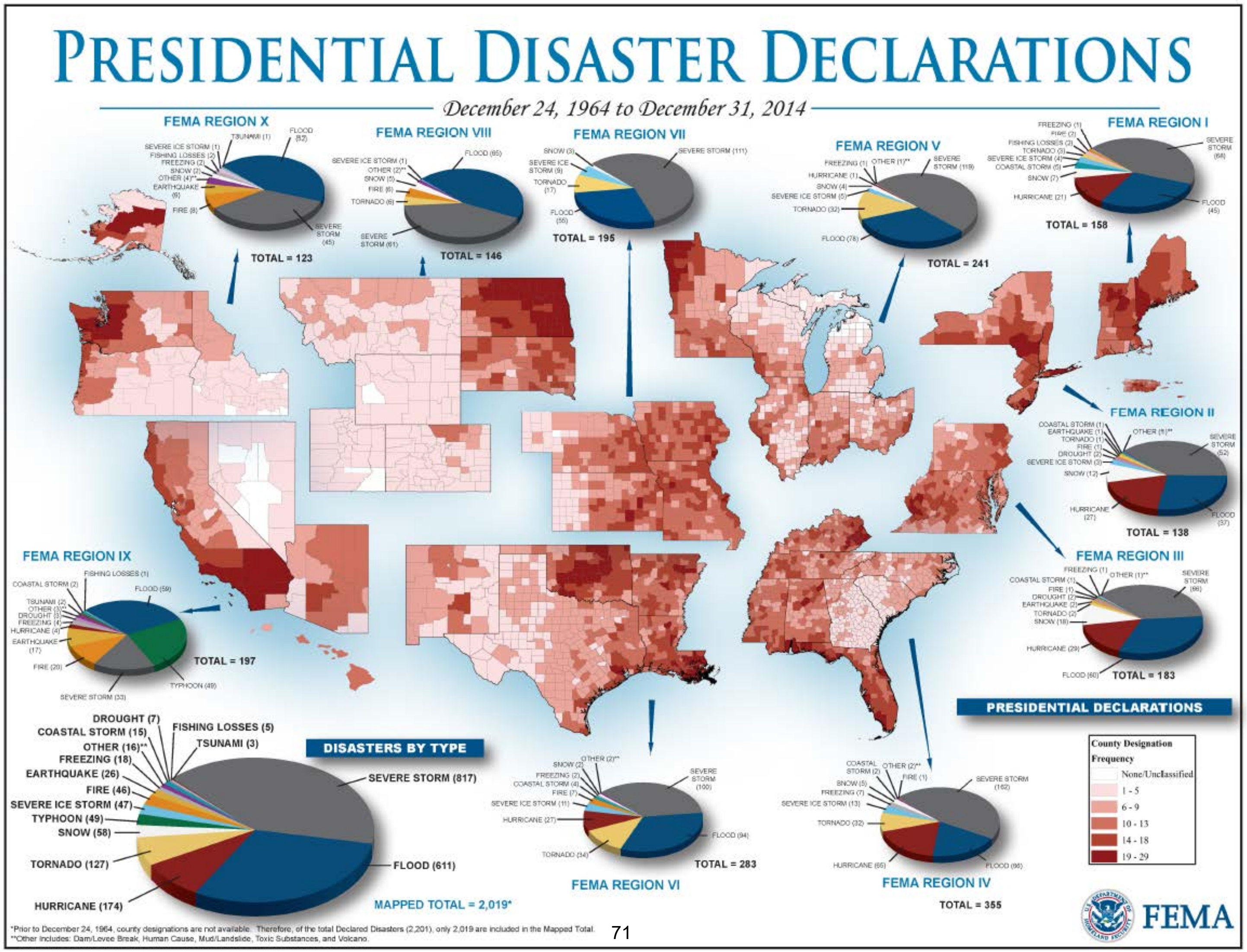
Summary

- Building codes are the foundation for community resilience
  - Whether the risk comes from earthquakes, flood, hurricanes, or tornadoes, we have the knowledge, capacity and ability to build in a way that allows us to bounce back more swiftly after disasters
  - And when we do, lives will be spared, communities will be preserved and resilience will be achieved

Summary

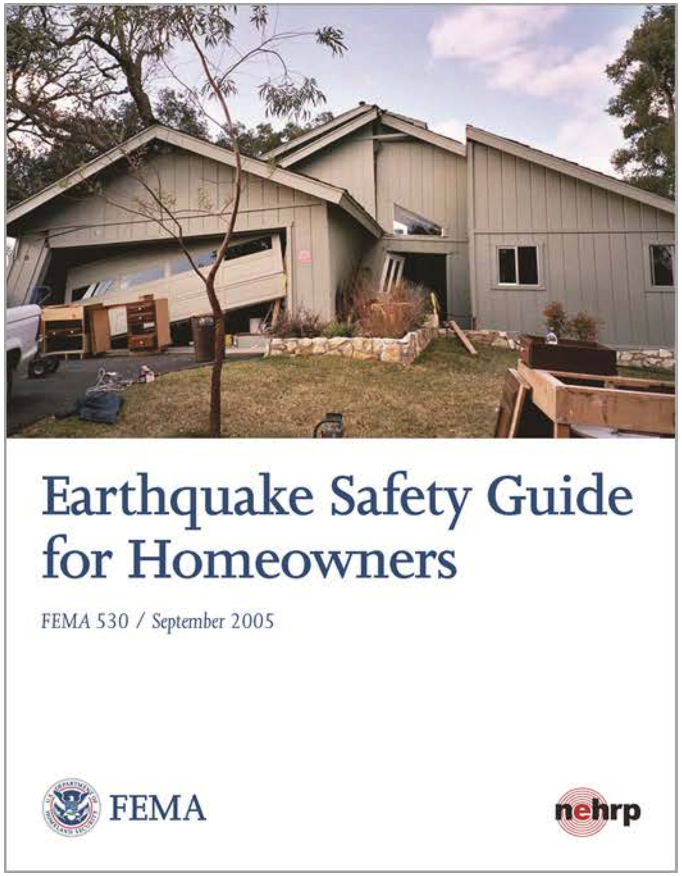
- Building code costs are small compared to benefits
  - Cost of materials and workmanship quality
  - Cost of administration and enforcement
- Studies have shown that Building Codes do not significantly increase overall building cost
  - Adoption of statewide codes can help reduce costs
- Studies have shown that adding adequate seismic provisions to a building code generally adds less than 2% to the overall cost of typical building construction

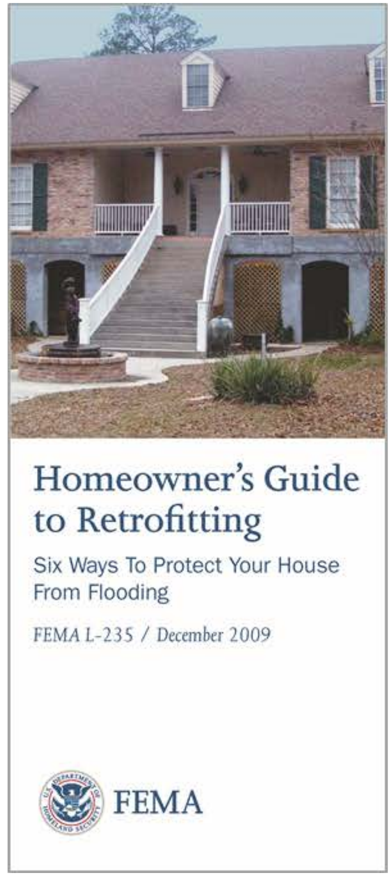
Summary – We can do a better job!

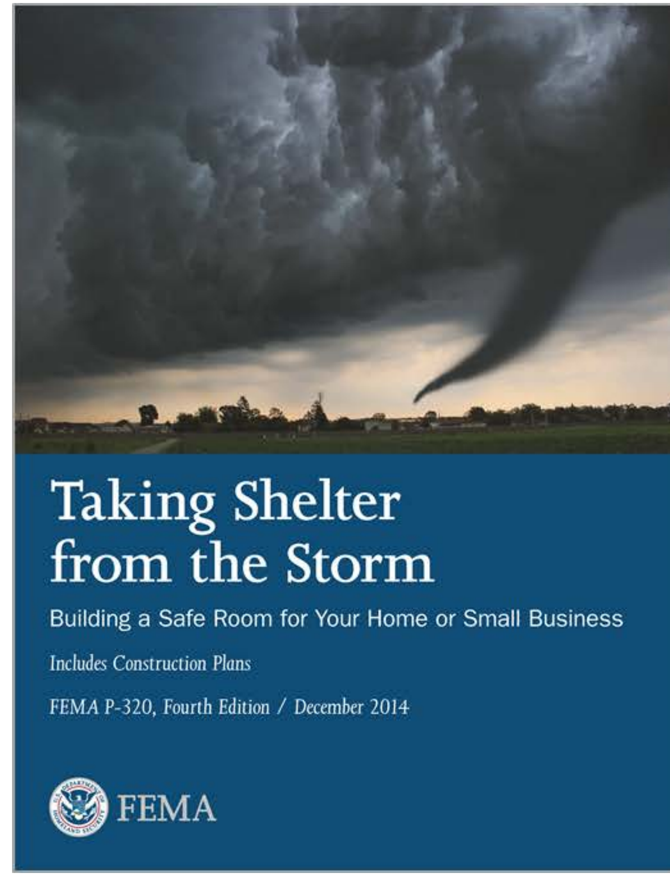


RESOURCES

FEMA Publications for Individuals and Homeowners







Resources

Publications

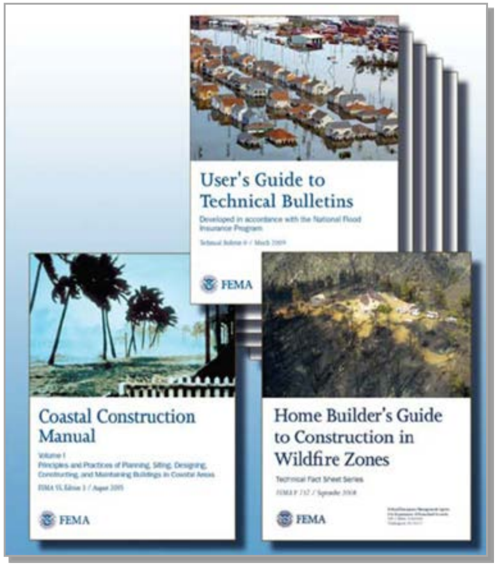
- FEMA Building Codes Toolkit: https://www.fema.gov/building-codes-toolkit
  - Property Owners and the General Public
  - Engineering and Design Professionals
  - Building Code Officials
- California Governor's Office of Emergency Services and FEMA, Guidelines to Strengthen and Retrofit your Home before the Next Earthquake, Revised October 2000.
- International Code Council: Government Relations Code Adoption Toolkit

Resources

FEMA Publications & Technical Guidance documents available in the FEMA Library (http://www.fema.gov/library)

Key Documents:

- FEMA Fact Sheet: Importance of Building Codes in Earthquake-Prone Communities Fact Sheet
- FEMA 313: Promoting the Adoption and Enforcement of Seismic Building Codes: A Guidebook for State Earthquake Mitigation Managers, January 1998.



Resources

FEMA Publications (continued)

- FEMA 909: Home and Business Earthquake Safety and Mitigation
- FEMA P-154: Rapid Visual Screening of Buildings for Potential Seismic Hazards – A Handbook, Third Edition, January 2015.
- FEMA E-74: Reducing the Risks of Nonstructural Earthquake Damage - A Practical Guide, Fourth Edition, Dec 2012.
- FEMA P-50: Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings, May 2012.
- FEMA 232: Homebuilders' Guide to Earthquake-Resistant Design and Construction, June 2006.
- FEMA 454: Designing for Earthquakes - A Manual for Architects, December 2006.
- FEMA P-749: Earthquake-Resistant Design Concepts, December 2010

Resources

Videos

- ICC: Welcome to Building Codes 101 – Understanding Building Codes (Part I) https://www.youtube.com/watch?v=Kk358ZZa8pk
- ICC: Welcome to Building Codes 101 – Understanding Building Codes (Part II) https://iccsafe.adobeconnect.com/_a739800700/p61108341/?launcher=false&fcsContent=true&pbMode=normal

Earthquake Resources

FEMA

Questions?