Life-Safety Risks to Schools from Nonstructural Earthquake Damage

2012 EERI ANNUAL MEETING AND
NATIONAL EARTHQUAKE CONFERENCE

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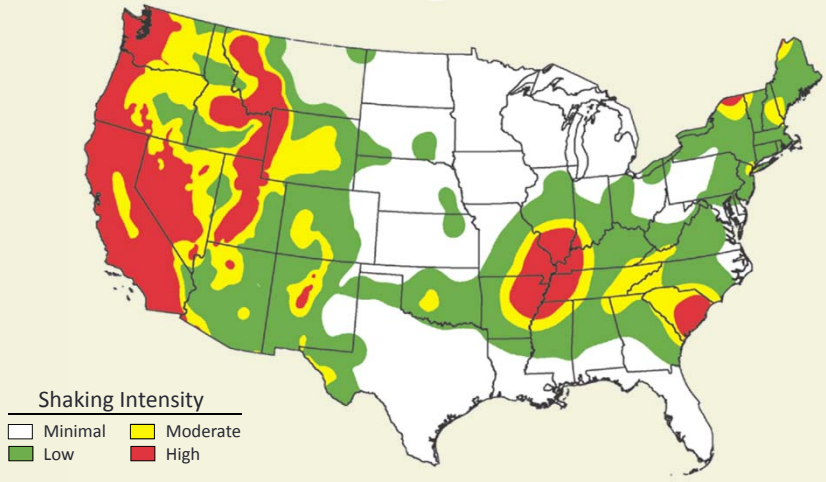
School Safety!

Presentation Outline

- Earthquake hazards affecting the Central US
- What are nonstructural components?
- Historical performance
- Benefits of mitigation
- Questions and answers

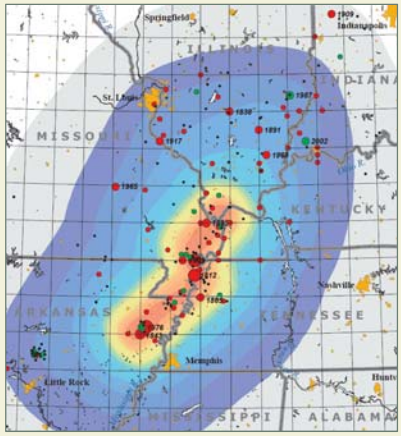
Earthquake Hazards Affecting Central US

Probable Ground Motion Intensity



Central US Earthquake History

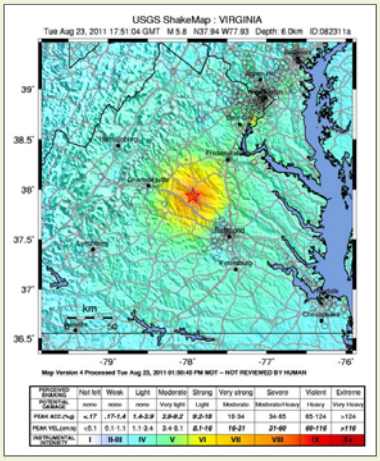
- 1811-1812: M7.7+, New Madrid, MO
- 1843: M6.0, Marked Tree, AR
- 1865: M5.0, Memphis, TN
- 1895: M6.6, Charleston, MO
- 1941: <M5.0, Covington, TN
- 1952: <M5.0, Dyersburg, TN
- 1956: <M5.0, Covington, TN
- Little bldg damage has occurred
  - Sparsely populated (early 1800s)
  - Chimneys, windows, contents



Earthquake Damage

- Mineral, VA: M5.8 (2011)

Even small EQs can be damaging



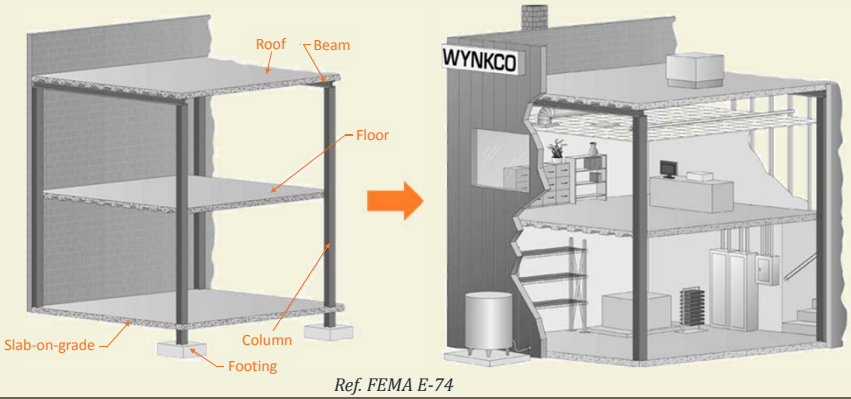
What are Nonstructural Components?

Structural Components

- Structural components resist gravity loads, lateral loads (wind & earthquake), and other types of loads
- Structural components include:
  - Roof
  - Floors
  - Beams
  - Columns
  - Braces
  - Concrete / masonry walls (Load bearing only)
  - Foundation

Nonstructural Components

- Nonstructural components include all portions of the facility that are not load-carrying / structural components



Ref. FEMA E-74

Categories of Nonstructural Components

Architectural Components

Mechanical, Electrical, Plumbing Components & Process Equipment

Furniture, Fixtures, and Contents

Architectural Components

- Parapets
- Partition walls
- Screen walls
- Ceilings
- Glazing
- Cladding
- Veneers
- Chimneys
- Stairs

Interior contents and ceiling damage

Mechanical, Electrical, & Plumbing

- Fire Protection Equipment
- Generators
- Chillers & boilers
- Distribution panels
- Transformers
- Fans & heaters
- Air handling units
- Ductwork & conduit
- Piping & plumbing

Diesel emergency generator (unanchored)

Furniture, Fixtures, & Contents

- Desks & chairs
- Bookcases & file cabinets
- Storage cabinets & racks
- Furniture
- Computers
- Smart boards
- Projection equipment

Lakeside School Library
Kern County Earthquake - 1952
Photo Credit – M. Knox

Structural & Nonstructural Components

- Structural systems
  - Designed by civil or structural engineer
  - Structural elements are shown on the construction drawings including the seismic lateral force resisting systems
  - Construction oversight to ensure bldg conforms to design drawings
- Nonstructural systems
  - Specified by design team (architect, mechanical / electrical engineer, interior designer, IT engineer, fire protection engineer, etc.)
  - Seismic design is via performance specifications TO BE IMPLEMENTED BY THE RESPECTIVE CONSTRUCTION TRADES
  - Performance specifications provide limited guidance on seismic design for contractor implementation
  - Little inspection or oversight to ensure proper installation

Nonstructural Component EQ Performance

Historic Performance

Earthquake Damage Concerns

Life Safety – Paramount: Children & Staff

- Could anyone be hurt by this building or component in an earthquake?

Property Loss

- Could a large property loss result?

Functional Loss – Community Shelter

- Could the loss of this building or component result in an outage, interruption or loss of use?

1933 Long Beach, CA Earthquake

Moderate Magnitude 6.3M

URM buildings heavily damaged

Property damage estimated at $40 million

115 fatalities

120 schools damaged

70 schools destroyed

Jefferson Junior H.S. Photo Credit – EERC

John Muir School
Photo Credit – Unknown

California's Response

- 1933 Long Beach Earthquake
- 1 month later California adopted the Field Act
- All school design, plans and construction authorized and supervised by the California State Department of Works Division of Architecture
- 6 years later Garrison Act enacted to regulate all school construction in the state

Jefferson Junior H.S. Photo Credit – TJ Maher

Sichuan, China Earthquake 2008

Magnitude Mw 7.9

6,900 school rooms collapsed

9,000 students & teachers perished

More than 1,000 students along perished at the Beichuan Middle School in Mianyang

Mineral, VA Earthquake M5.8

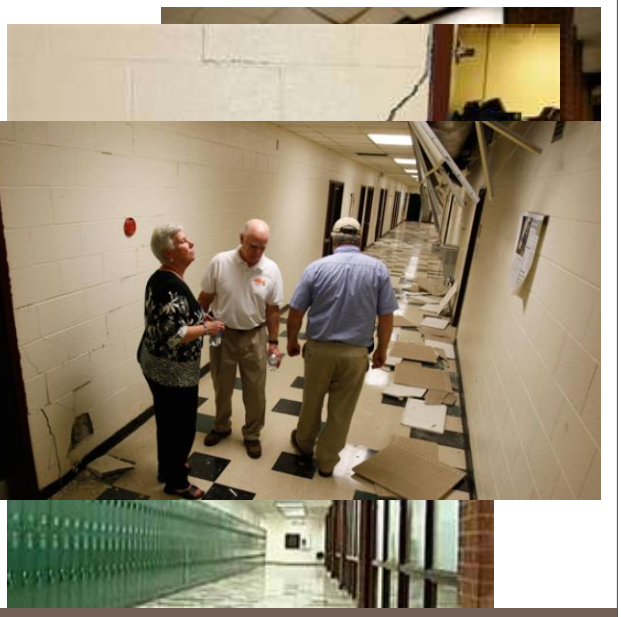
Small magnitude event

Infrequent activity regionally for moderate and large events

No fatalities

Estimated losses $200-$300 million

Nonstructural damage to Louisa County High School



Louisa County High School

Primary Contributors to Nonstructural Damage

1. Code Design Philosophy

   Life safety performance

   Nonstructural Design Importance Factor:

   - Life safety system
   - Contains or transports hazardous materials
   - Required to operate/function following an earthquake event

Primary Contributors to Nonstructural Damage

1. Code Design Philosophy
2. Not all components governed by code
   - Bookcases
   - Screen
   - Projector
   - Desks

Primary Contributors to Nonstructural Damage

1. Code Design Philosophy
2. Not all components governed by code
3. Design Professional Knowledge of seismic design & responsibility

Knowledge & Responsibility?

- Engineers
  - Structural
  - Mechanical
  - Plumbing
  - Fire protection
  - Electrical
  - Telecom
- Architects
- Building Officials
- Owners

- General Contractor
- Subcontractors
  - Fire Protection
  - Cladding
  - Mechanical
  - Plumbing
  - Electrical
  - Drywall
  - Ceiling
  - Telecom
- Installers
- Equipment vendors
- Inspectors
- Tenants
- Facility Managers
- Office Manager

Responsibility?

Primary Contributors to Nonstructural Damage

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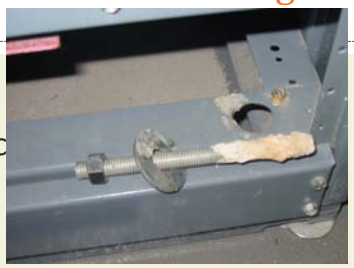
3. Design Professional Knowledge of seismic design & responsibility
4. Construction quality & enforcement



Benefits of Mitigation

Benefits of Nonstructural Mitigation

1. Life-safety risks significantly reduced and controlled
   - Students
   - Staff
   - Visitors

Benefits of Nonstructural Mitigation

1. Life-safety risks significantly reduced and controlled
2. Repair & recovery costs significantly reduced
3. Availability as a community shelter in time of need
4. Greatest cost-benefits achieved
   - FEMA – National Average: $4 Benefit for every $1 spent
5. Many nonstructural mitigation measures are easily implemented by staff

Mitigation Measures

- Implement good housekeeping measures
- Relocate contents to lower
  - Egress routes
- Restrain contents
- Install proper equipment anchorage

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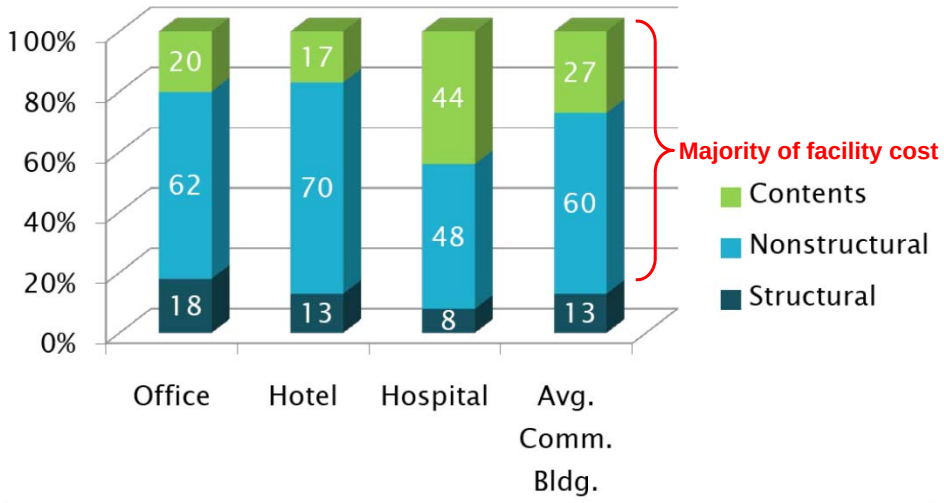
Nonstructural Costs



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AND

7. Life-safety risks are significantly reduced and controlled

Nonstructural Mitigation Resources

- FEMA E-74
  http://www.fema.gov/plan/prevent/earthquake/fema74/
- FEMA 412 – Installing Seismic Restraints for Mechanical Equipment
- FEMA 413 – Installing Seismic Restraints for Electrical Equipment
- FEMA 414 –Installing Seismic Restraints for Duct & Pipe
- FEMA 395: Incremental Seismic Rehabilitation of School Buildings (K-12)
- ASCE – Earthquake Protection of Building Equipment and Systems, by Gatscher, McGavin & Caldwell

Final Thoughts

Questions?

IF YOU HAVE ADDITIONAL QUESTIONS
PLEASE CONTACT ME AT:

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