Retrofitting in the Central US: A Federal Perspective

2012 National Earthquake Conference

Michael Mahoney
FEMA, Building Science Branch

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NATIONAL EARTHQUAKE CONFERENCE

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National Earthquake Hazards Reduction Program (NEHRP)

- NEHRP was formed by Congress in 1977 to lead federal government "to reduce the risks of life and property from future earthquakes in the US…"
- Four primary agencies:
  - USGS: earth science research and hazard identification
  - NSF: basic research
  - NIST: applied research and standards development
  - FEMA: implementation of program goals / products
- Under NEHRP, FEMA's goal is to reduce future losses.
  - However, NEHRP has no regulatory authority.
  - Activities: encourage better practices (codes), improve public awareness and outreach, and support State and local partners.

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FEMA Earthquake Program

- Under NEHRP, FEMA is responsible for:
  - Supporting State earthquake activities.
  - Increase public awareness of earthquake risk and how it can be mitigated.
  - Developing seismic guidance documents for new and existing buildings based on new research data and loss experience.
  - Support placing seismic design guidance in the nation's model building codes and standards, and support code adoption at the state and local level.
  - A listing of almost 100 FEMA earthquake publications is available at:

http://www.fema.gov/plan/prevent/earthquake/pubindex.shtm

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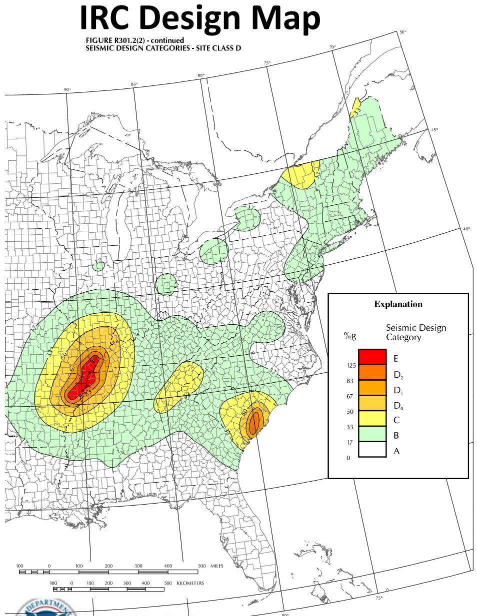
IRC Design Map



USGS New Madrid Earthquake Probabilities For a 50 year Window:

- **Repeat of 1811 -1812 (Magnitude 7.5-8.0)**
  - ~10% chance
- **Severe Damaging EQ (Magnitude 6.0)**
  - ~30% chance

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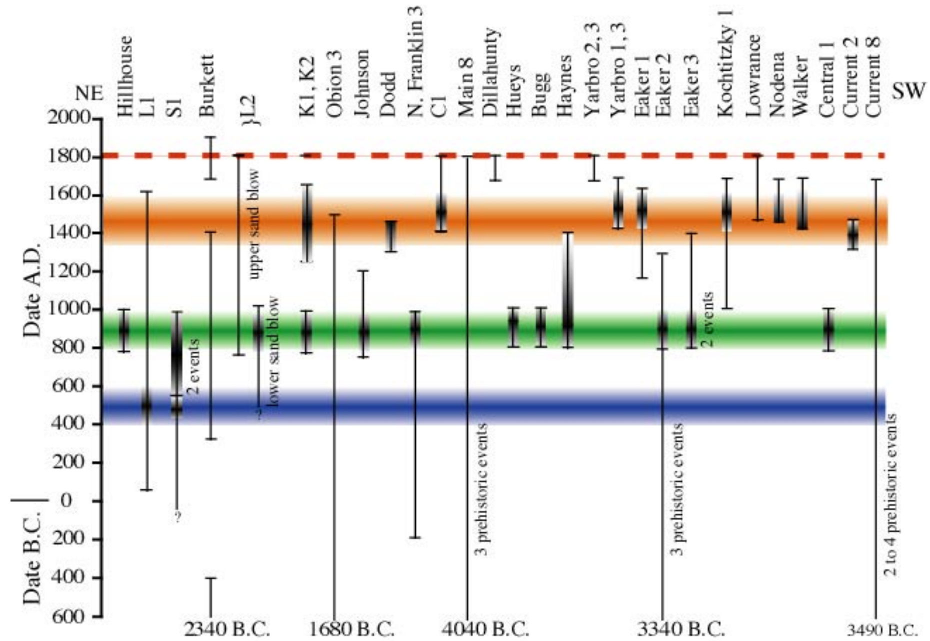
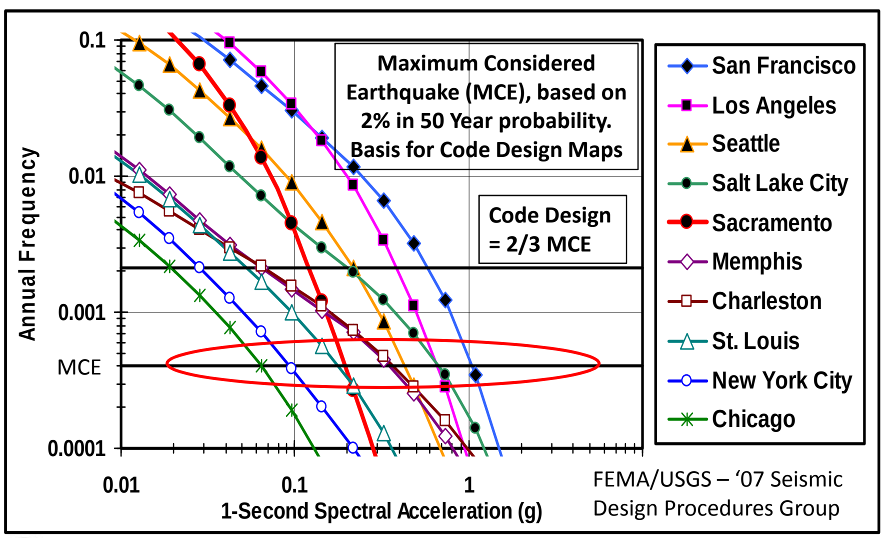


900, 1450, 1811-1812 > ~500 year repeat time! From USGS

Hazard Curves for WUS vs. CUS Cities



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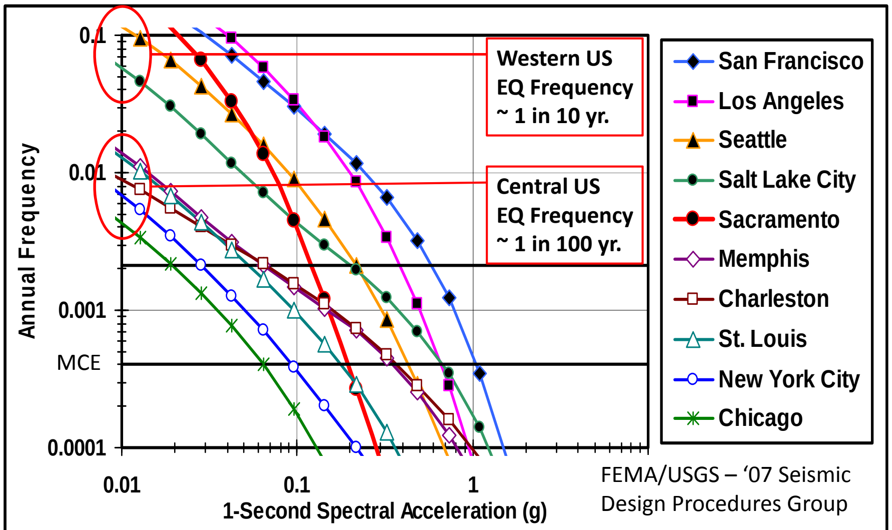
Hazard Curves for WUS vs. CUS Cities



FEMA/USGS – '07 Seismic Design Procedures Group

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What This Means…

- The take away is that the USGS hazard curves show that a damaging western US earthquake can be expected roughly once every 10 years, while a damaging central US earthquake can be expected roughly once every 100 years.
- Therefore, the Central US should have more time between damaging earthquakes to address risk from existing buildings.
- This additional time could be taken into account in planning a State and/or local existing buildings policy.
- This would allow scarce resources to be better focused.
- One national existing buildings policy does not fit all, especially in Central US.

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Cost Effective Retrofitting

- Such a Central US seismic retrofitting policy could include allowing low to moderate risk structures to be replaced with new code-compliant structures or code-triggered upgraded structures as they reach the end of their useful lives.
  - Low to moderate structures = Risk Category I and II buildings as defined in Section 1604.5 of the *International Building Code*.
- Scarce seismic retrofitting resources could then be focused on high risk and critical structures.
  - High risk and critical structures = Risk Category III and IV as per IBC.
- Such a policy would need to include two critical elements.
- The first element would be sufficient emergency response capability to respond to a potentially increased number of building failures and the resultant casualties.
  - FEMA Urban Search and Rescue was formed with NEHRP support.

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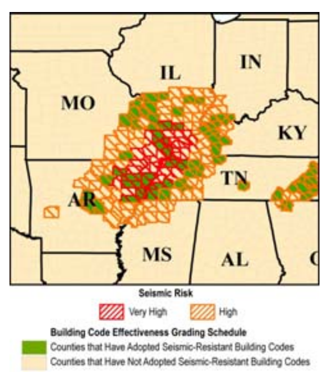
Building Code Issues

- The second required element of such an existing buildings policy would be the adoption and effective enforcement of a suitable building code for new buildings and triggered code upgrades.
- Evaluation of local building codes and code departments is performed by ISO Building Code Effectiveness Grading Schedule (BCEGS).
- BCEGS data was recently used by FEMA to evaluate State and local code adoption within the New Madrid Seismic Zone.



Map showing the counties in the NMSZ with high seismic risk and their code adoption for commercial buildings (December 30, 2010 BCEGS Data)

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BCEGS Central US Code Adoptions

- **Arkansas** adopted 2006 International Codes as state codes, which are mandatory minimum requirements. Local codes required to be in accordance with state codes.
- **Illinois** has no statewide mandatory codes in place. Building code adoption and enforcement is the responsibility of local jurisdictions.
- **Indiana** has mandatory statewide codes based on the 2006 IBC and 2003 IRC, and requires mandatory enforcement.
- **Kentucky** has adopted the 2006 IBC and 2006 IRC with amendments that weakened the codes by lowering seismic design categories. Kentucky Building Code is mandatory statewide; local jurisdictions may not amend.
- **Mississippi** does not have statewide building codes. Building code adoption and enforcement is the responsibility of local jurisdictions.
- **Missouri** relies on the local jurisdictions to adopt and enforce their own building codes. Lowest class communities not permitted to adopt a code.
- **Tennessee** adopted the 2006 IBC in September 2008 as the statewide code and adopted the 2009 IRC effective October 1, 2010.

Data from ISO BCEGS NMSZ Report

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Cost of Using of Building Codes in CUS -1

- The cost of complying with the seismic provisions of a building code has always been used as an issue against their adoption.
- In 1985, FEMA published a series of Design Examples using the new 1985 NEHRP Provisions, which compared the cost of seismic design to several local codes.
- The study compared 54 building designs performed in 8 cities throughout the country (inc. Memphis) by 17 design firms.
- The study concluded that the <u>average</u> additional cost for including seismic requirements was ~5% of structural cost, which translated into ~1½% of total building cost.
- While this data is 27 years old, as a yardstick it is still valid.

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Cost of Using of Building Codes in CUS - 2

- In 2004, FEMA funded a small study to compare seismic design between the 1999 SBC and the 2003 IBC in the Central US, as adoption of the IBC had been raised as an issue.
- As a cost surrogate, the study compared the ratio of weight of required structural materials for 8 buildings using both codes.

SAMPLE BUILDING	RATIO WT. (IBC/SBC)
Steel moment resisting frame 3 story office building	1.04 total steel / 1.12 LFRS
Steel moment resisting frame 6 story office building	0.93 total steel / 0.81 LFRS
Concrete tilt up wall / steel frame warehouse	1.0 conc & steel / 1.04 reinf.
Concrete masonry one story retail shopping center	1.0 conc / 1.05 wall reinf.
Concrete masonry one story school	1.0 conc / 1.14 wall reinf.
Concrete frame / shear wall 4 story parking garage	1.0 conc / 1.64 wall reinf. / 1.02 total reinforcing steel
Concrete frame / shear wall 10 story condominium	1.0 conc / 1.65 column reinf. 1.11 total reinforcing steel

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Cost of Using of Building Codes in CUS - 3

- New NIST project to analyze the relative costs and benefits of applying earthquake-resistant codes for buildings in NMSZ.
- Reason is information on cost of seismic resistant construction is largely anecdotal, leading to varying perceptions on the costs and benefits of implementing national seismic codes.
- Are we overestimating the need and cost of seismic codes?
- Project combines local practitioners with experts in seismic design to use case studies to assess costs and benefits.
- Each case study to use: 1) no seismic code (wind and gravity), 2) local seismic code, 3) 2009 NEHRP Seismic Provisions.
- The Phase 1 Report due the end of 2012.

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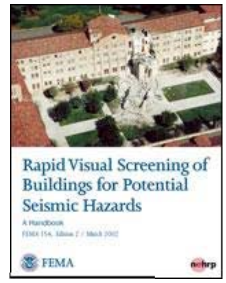
Identifying At-Risk Existing Buildings

- The first step in the retrofitting process is identifying at-risk existing buildings.
- Rapid Visual Screening (FEMA-154)
  - Provides screening method and forms for rapid survey of buildings by non-technical personnel.
  - Currently being updated (ATC 71-4) to add new technology and resources.
- FEMA 154 ROVER
  - Electronic version of FEMA 154 for handheld or smart phone devices.
  - Completed, software app soon to be released.
- HAZUS, particularly AEBM, can also be used to identify at-risk buildings.



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HAZUS MH
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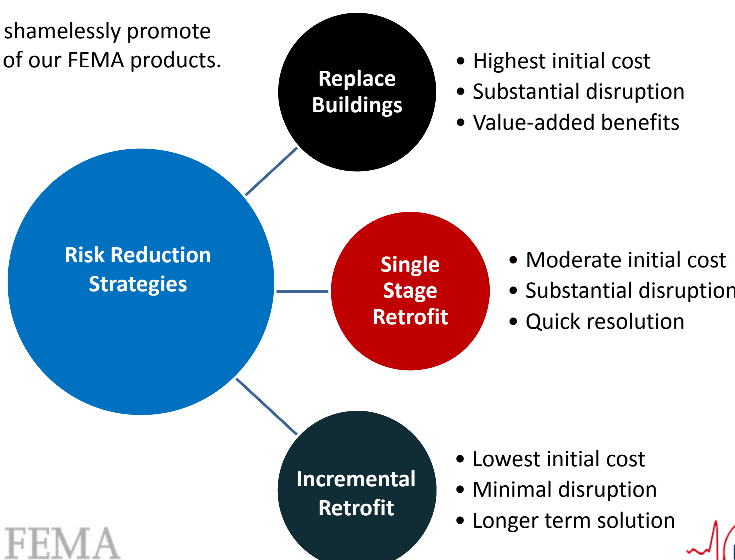
Strategies to Mitigate CUS Earthquake Risk*

* and shamelessly promote some of our FEMA products.



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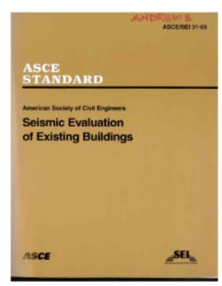
Federal Funding of CUS Retrofitting

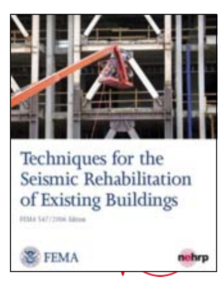
- The FEMA Hazard Mitigation Grant Program (HMGP) can be used to fund seismic retrofitting.
  - HMGP is a post disaster grant program funded by a percentage of a state's disaster funds. Projects are not tied to the disaster.
- CUS seismic retrofitting projects funded under HMGP:

Infrastructure Retrofitting in Clay County, Arkansas	1997	$13,069
Seismic Retrofit of a School Building in Piggott, AR	1997	$448,538
Infrastructure Retrofitting in Poinsett County AR	1997	$51,017
Seismic Retrofit of a School Building in Clay, AR	1997	$484,268
Seismic Retrofit of a Community Center in Crittenden County, AR	1997	$76,164
Seismic Retrofit of a School Building in Piggott, AR	1997	$157,675
Earthquake Hardening of Public Facility in West Memphis AR	1999	$269,452
Seismic/Wind Retrofit of Bragg Elementary, West Memphis School District, AR	2001	$750,287
Seismic Retrofit of Waterloo Community Unit School in Monroe County, IL	2006	$659,238
Creal Springs School Hardening in Williamson County, IL	2009	$443,276
Seismic Infrastructure Mitigation, Memphis, TN Light, Gas and Water	1998	$2,608,221

Seismic Retrofitting Options

- Full Seismic Retrofitting of Buildings
  - Advantage: Complete retrofitting reduces seismic risk to an acceptable level.
  - Disadvantage: Expensive, difficult to justify in low seismic areas, potential loss of use during retrofit.
- Justifiable if focused on:
  - Hospitals and other facilities critical to response.
  - High risk structures due to high occupancy, hazmat.
- Retrofitting Process:
  - Evaluate hazardous buildings using ASCE 31/41.
  - Design retrofit using ASCE 41.
  - FEMA 547 to identify techniques to meet ASCE 41.
  - Meet IBC Chapter 34, Existing Structures or IEBC.





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Alternate Retrofitting Options

- There are other seismic retrofitting options for the CUS beyond full seismic retrofitting as specified ASCE- 41.
- These other seismic retrofitting options can also include other more targeted actions, such as:
  - Reliance on building turnover, with new buildings meeting new code.
  - Incremental Seismic Retrofitting methods.
  - Specific targeted retrofitting methods, such as weak stories.
  - Nonstructural mitigation.
  - Residential retrofitting.
  - Residential nonstructural mitigation.
  - Innovative public awareness and outreach.

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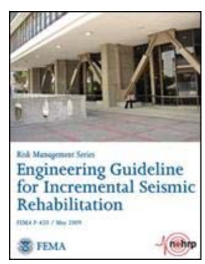
Incremental Seismic Retrofitting

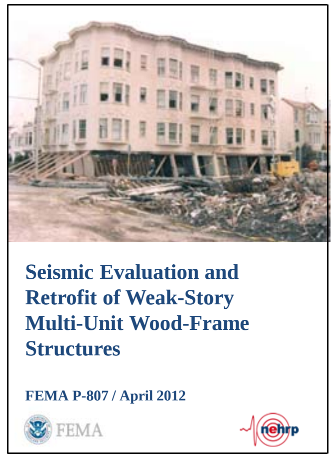
- Incremental Seismic Retrofitting (ISR)
  - Advantage: cost effective, focuses on specific area
  - Disadvantage: not full retrofit, some risk remains
- Incremental Seismic Rehabilitation series
  - FEMA 395 – Schools
  - FEMA 396 – Hospitals
  - FEMA 397 – Offices
  - FEMA 398 – Apartments
  - FEMA 399 – Retail
  - FEMA 400 – Hotels
  - FEMA P-420 Engineering Guideline



- Goal is to perform retrofitting on key components during scheduled maintenance.
  - Example: bracing parapets during re-roofing.

Targeted Seismic Retrofitting

- New technique to more effectively retrofit weak story wood buildings.
- Seismic Evaluation and Retrofit of Weak-Story Multi-Unit Wood Frame Structures (FEMA P-807).
  - Developed in coordination with the San Francisco CAPPS Project.
  - Targets "Marina District" and Northridge style soft story multi-unit wood frame residential structures.
  - Retrofit is limited to weak story only.
  - Includes calculation tool to account for strength of all walls in the building, including non-structural.
  - To be available from FEMA this fall (but please don't order it yet) and on NEHRP, ATC and NEES websites.


Seismic Evaluation and Retrofit of Weak-Story Multi-Unit Wood-Frame Structures

FEMA P-807 / April 2012

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Nonstructural Retrofitting

- Nonstructural damage accounts for most earthquake damage and can result in loss of use of a building.
  - Piping failures closed ½ hospitals in the 1994 Northridge earthquake.
- Nonstructural components include:
  - Architectural building components.
  - Mechanical, electrical and plumbing components.
  - Furniture, fixtures and equipment.
- Types of nonstructural risk include:

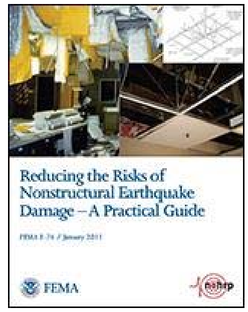
Life safety

Property loss

Functional loss

Nonstructural Mitigation Guide

- Nonstructural Design Guide (FEMA E-74)
  - Recently improved, web-based design guide.
  - Provides design guidance for over 70 different nonstructural components.
  - For each component, guide provides examples of damage and plans or photos of the recommended mitigation technique.
  - Includes technical specifications, risk rating forms and sample inventory checklists.
  - Short web-based and longer NETAP-based technical training materials and now available
  - New update to capture recent earthquake data.



- http://www.fema.gov/plan/prevent/earthquake/fema74/index.shtm

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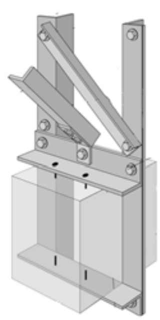
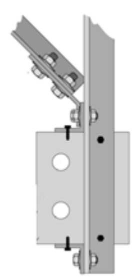
Nonstructural Retrofitting

- Advantages: Effective at reducing risk of loss of use from n/s damage, cost effective for critical or high risk facilities, high cost-benefit score.
- Disadvantage: Nonstructural retrofitting is only appropriate where the structure is seismically safe. It is not appropriate for collapse hazard buildings without structural retrofitting.





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Seismic Rating of Residential Buildings

- *Simplified Seismic Assessment Procedures for Detached, Single-Family, Wood-Frame Dwellings* (ATC 50) developed after Northridge earthquake for City of LA using HMGP funds.
  - ATC 50 finished and extensively tested, but not implemented.
  - Includes retrofitting guide (ATC 50-1) and implementation guide (ATC 50-2)
- Simplified Seismic Assessment Form included the dwelling's structural and non-structural systems, hazard, and site conditions.
- Assessment Form is used to calculate a Seismic Performance Grade based on Structural Score and Seismic Hazard Score.
- The form provides a list of conditions that, if seismically retrofitted, would allow the owner to improve the seismic grade.
- ATC-50 currently being updated to become FEMA P-50 for national use to rate seismic performance of housing.

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Seismic Rating of Residential Buildings

- The FEMA P-50 update project is being co-sponsored by CEA; funded a revised score to damage conversion table.
- The FEMA P-50 system assigns a rating score based on:
  - Foundation (type, slope, anchorage)
  - Framing and Configuration (irregularities, heavy roof or wall materials)
  - General Condition Assessment (evidence of deterioration)
  - Nonstructural Elements (chimney, water heater anchored, veneer)
  - Local Site Conditions (sloped lot, cut and fill pad, settlement)
  - Regional Seismic Score (S_{DS}, ground failure, liquifaction, faulting)
- Identifies items that can be retrofitted to improve scoring.
- FEMA P-50-1 is a retrofitting guide to provide assistance.
- FEMA is only providing the tool, it is up to others to use.

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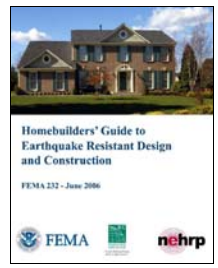
Residential Retrofitting

- Residential Retrofitting can be cost-effective.
  - Foundation bolting may be the most effective option given the number of older homes not anchored.
  - This has the added advantage of providing a significant benefit for wind and other hazards.
- Guidance provided in FEMA Seismic Rehabilitation Training (FEMA P-593 CD).
- Some guidance also provided in FEMA Homebuilders Guide for Earthquake Resistant Design and Construction (FEMA 232).
  - Anchorage of Home Contents (Chapter 8)
  - Existing Buildings (Chapter 9)



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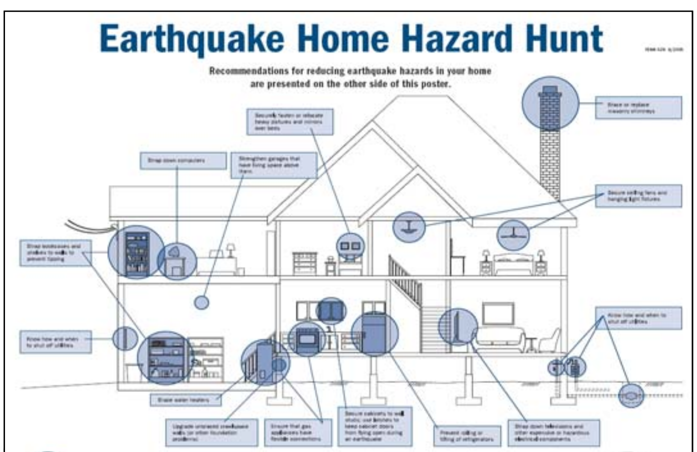
Residential Nonstructural Retrofitting

- Increase public earthquake awareness and non-structural mitigation using tools like FEMA Home Hazard Hunt poster.



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Public Outreach and Awareness Partners

- FEMA worked with the Federal Alliance for Safe Housing (FLASH) and Disney to help develop StormStruck: A Tale of Two Houses, an interactive event at Disney World EPCOT.
- With StormStruck as a proven model, Disney has conducted research and expressed their intention for California Disneyland to develop a similar experience for earthquakes.

Results of Disney Earthquake Research

- 78% of respondents experienced an earthquake
- 80% of respondents do not have earthquake insurance
- 37% of respondents have homes built earlier than 1980
- 45% of respondents want to know how to prepare for an earthquake
- 69% of respondents would spend money to protect their homes from earthquakes if it increased the safety of their family, home or valuables
- 41% of respondents would spend $2,500 or more to improve their homes
- 78% of respondents would be more likely to act on do-it-yourself recommendations rather than information on hiring a contractor
- 23% of respondents preferred information on how to protect their home, 21% preferred information on how to protect their contents, and 56% preferred information on both

Conclusions

- The Central US offers a unique opportunity to tailor programs for retrofitting of existing buildings to better fit the hazard.
- Existing buildings are a risk that need to be addressed.
  - Seismic retrofitting justifiable in some cases, such as critical facilities.
  - Economically justifiable measures (incremental and nonstructural) may be more feasible for other types of structures.
  - Enforcing a building code for new buildings and code triggered upgrades as they replace existing older at-risk buildings also effective.
- There are steps that the CUS can take to reduce future risk.
  - Such steps must take into account the reality of limited resources.
  - Target those resources towards critical or higher risk structures and then allow the normal building life cycle to replace other older buildings with code compliant new buildings.

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