INSTRUCTORS GUIDE
FEMA P-767 CD, Earthquake Mitigation for Hospitals

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This Instructors Guide contains useful information that should be read by the Instructor before presenting this course. The first part of this Guide contains an overview and summary of the course; relevant background information; places this course in geographical context; provides recommendations on how to tailor the content to your audience; and lists the course handouts. The second part of this Guide provides the Answer Key to the Student Exercises.
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PART 1

The goal of the ***FEMA P-767 CD, Earthquake Mitigation for Hospitals*** is to promote seismic rehabilitation of hospitals, in order to reduce earthquake damage losses and business interruption following moderate to major earthquakes. This is accomplished by introducing the trainee to the effect of earthquakes to a variety of common building types and typical hospital equipment and components, identifying common structural and nonstructural seismic vulnerabilities, and identifying rehabilitation approaches and available guidelines.

The Applied Technology Council developed this training with funding provided by the Federal Emergency Management Agency. Comments and questions regarding this training should be directed to the Applied Technology Council (www.atcouncil.org).

Overview
The following is an overview of the training, which is divided into eleven sections. The number of slides and approximate presentation time is noted for each section.

Section 1 - Introduces the training course, defines applicable terminology, and introduces by case example why seismic rehabilitation of hospitals is important. (13 slides/20 minutes).

Section 2 - Introduces earthquake hazards, including ground shaking, fault rupture, and liquefaction. Discusses the difference between earthquakes occurring at plate boundaries and intra-plate occurrences and introduces seismic hazard maps. (14 slides/20 minutes). This section is generic and the presenter is strongly encouraged to add regional hazard data pertinent to the audience.

Section 3 – Introduces seismic vulnerabilities of building structures and discusses how to identify vulnerable conditions and likely earthquake behavior. Typical damage for a variety of building types is provided pictorially to illustrate expected damage to these building types. (42 slides/45 minutes).

Section 4 – Introduces seismic vulnerabilities of nonstructural components, equipment and systems, including building utilities, architectural components, medical equipment, medical gases, and furniture and contents. Discusses the cause and significance of nonstructural damage and pictorially shows representative nonstructural earthquake damage. (41 slides/45 minutes).

Section 5 – Presents a general summary of expected earthquake damage to a region experiencing a major earthquake. Discusses conditions that would likely exist following a major earthquake event for existing hospitals. A brief discussion of the design and construction process, as it relates to seismic design and performance of nonstructural components is also presented. The Section ends with the presentation of a summary of hospitals that have experienced an earthquake and the performance experienced. (33 slides/30 minutes).

Section 6 – Provides the transition of the presentation from discussing seismic risk to implementing risk reduction or mitigation measures. Discusses seismic risk reduction strategies pertinent to hospitals. (2 slides/10 minutes).

Section 7 – Introduces the process for planning and effectively managing and implementing a facility seismic mitigation program for a hospital organization. (35 slides/45 minutes).

Section 8 – Introduces seismic mitigation for building structures and its integration into a hospital facility mitigation program. Challenges and conditions unique to hospitals are also discussed. (37 slides/45 minutes).

Section 9 – Introduces seismic mitigation of nonstructural equipment, components, and contents, as well as the integration into a facility mitigation program. Discussion of design tools and resources for nonstructural mitigation is provided. Numerous examples are provided to illustrate appropriate nonstructural seismic restraints. (74 slides/60 minutes).

Section 10 – Discusses specific opportunities where earthquake mitigation can be integrated into existing hospital facility programs. (16 slides/15 minutes).

Section 11 – Conclusions and summary of the workshop including an overview of vulnerability assessment, planning for mitigation, implementing mitigation, and integrating mitigation activities into existing programs are presented. (6 slides/15 minutes).

In order to tailor this training to the particular audience and not exceed the time available, it may be necessary to pick and choose among these 11 sections. The trainer should feel free to choose among the parts as appropriate to the audience and time available.

The presentation times above total nearly six hours. Past presentations given have totaled 7-8 hours with breaks (excluding lunch). Depending on your audience and how you run the training (will you allow yourself to be interrupted with questions, or will you hold questions/ discussion to the end?) the complete training might be compressed to 4 hours, or could take all day. It is recommended that the less technical the audience, the more you should compress the training, possibly removing parts from sections 3, 4, 8 & 9 thereby focusing more on the planning and integration processes of risk reduction and mitigation. Remember that you will need to budget time for lunch and breaks.

The following provides a brief discussion on background information related to this workshop, who the intended audience should be, and recommended handout materials.

Background
There is a significant amount of guideline material addressing seismic rehabilitation measures available, but much of it is not specific to hospitals as it resides in various places and in various forms. Therefore, the focus of this training is to provide an overall context for identifying and prioritizing structural and nonstructural vulnerabilities, and introducing a process for planning, managing, and implementing a seismic mitigation program that is specific to a hospital organization's existing operational processes and activities. The workshop has been developed based on FEMA 396. It is strongly recommended that instructors contemplating the presentation of this training course read FEMA 396.

Audience
This training is intended for those involved in facility management of hospitals, and others involved in making policy decisions regarding seismic rehabilitation of hospitals. This training assumes a low to moderate level of familiarity with seismic hazards and building construction. The audience may at times include insurance persons and some additional explanation of terminology and concepts may be necessary for these audiences. It is also understood that the audience may include one or many of the audience types named above. While the entire training is meant to be presented to all of these audiences, some of the eleven presentation sections might be removed or reduced for a particular audience. The trainer should review all sections before the training is held, determine the composition of the audience, and tailor the training accordingly.

Handout Materials
The FEMA P-767 CD contains:

1. The presentation slides (P-767 Earthquake Mitigation for Hospitals, Sections 1 through 11).

If funding is available, it is recommended that a handout of the slide set be printed (2 to 3 slides per page) and provided as a handout for workshop participants. Participants can then make appropriate notes within the handout.

Additional handout materials to consider providing to the attendee's are the FEMA documents referenced throughout the presentation slides, particularly on nonstructural components. These documents are free and can be ordered in bulk directly from FEMA and are listed below. It is encouraged that the workshop be coordinated with the local

State Earthquake Program Director as well as the FEMA regional Earthquake Program or Educational Director.

FEMA documents suggested as handouts:

2. FEMA 396, *Risk Management Series, Incremental Seismic Rehabilitation of Hospital Buildings, Providing Protection to People and Buildings*, December 2003.
3. FEMA 74, *Earthquake Hazard Mitigation for Nonstructural Elements, A Practical Guide,* September 1994. An updated version or e-doc of FEMA 74 is scheduled for release in 2010 from FEMA's web site.
4. FEMA 154-CD, *Rapid Visual Screening of Building for Potential Seismic Hazards, Edition 2*, July 2005.
5. FEMA 412, *Installing Seismic Restraints for Mechanical Equipment*, August 2005.
6. FEMA 413, *Installing Seismic Restraints for Electrical Equipment,* January 2004.
7. FEMA 414, *Installing Seismic Restraints for Duct and Pipe,* December 2004.

PART 2
STUDENT EXERCISE ANSWER KEY

Section 1: Introduction
Identify whether the following statements are true (T) or false (F).

(T) F 1.1 Earthquake risk to a facility is a function of both the hazard and the vulnerability.

T (F) 1.2 Only major structural damage to a facility can result in evacuation and long-term disruption of facilities.
Nonstructural damage, such as fire sprinkler water leakage, can also result in evacuation and long-term disruption to hospital operations.

Section 2: Earthquake Hazards
Identify whether the following statements are true (T) or false (F).

T (F) 2.1 Major earthquakes only occur along plate boundaries where large crustal blocks move past one another.
Earthquakes also occur away from plate boundaries, particularly in the central and eastern US. Earthquakes on the New Madrid Seismic Zone are intraplate events.

T (F) 2.2 Most areas of the country require no consideration for earthquake design under the International Building Code (IBC) because the seismic hazard is very low.
Very few areas of the county are completely exempt from all earthquake design provisions under the IBC. Dependent upon the facility occupancy importance (hospital, fire, police, etc.), critical facilities in moderate and low seismic hazard regions require seismic design.

2.3 Which of the following are earthquake hazards?
(Circle all that apply)

(a.) Fault Rupture
b. Typhoon
c. Riverine Flooding
(d.) Landslide

Section 3: Building Structural Vulnerability

3.1 Rank the following building types in terms of expected earthquake performance from 1 to 4, where 1 is the best performance and 4 is the worst.

_*3*_ Concrete Tilt-up

_*4*_ Unreinforced Masonry

_*1*_ Steel Braced Frame

_*2*_ Steel Moment Frame

3.2 Identify the conditions shown in each of the following illustrations, as follows: Soft Story, Adjacent Building Pounding, Plan Irregularity, Vertical Setback, and Diaphragm Discontinuity

Soft Story

Vertical Set-back

Plan Irregularity

Adj. Bldg. Pounding

Diaphragm Discontinuity

Plan Irregularity

Plan Irregularity

Vertical Set-back

Adj Bldg. Pounding

3.3 List four seismic performance predictors for buildings.

Building Type, Building Age, Quality of Construction, Design Code, Plan Irregularities, Vertical Irregularities (Set-backs, Soft Story), Diaphragm Discontinuities, Adjacent Building Pounding

Section 4: Nonstructural Vulnerability to Earthquakes

4.1 Name two nonstructural components included in each of the following categories:

Building Utilities: *Emergency Generator, Fire Pump, HVAC, Boiler, etc.*

Architectural Components: *Partition Walls, Ceilings, Light Fixtures, Parapets*

Medical Equipment: *CT Scans, MRI, Pharmacy*

Furniture & Contents: *Computers, Bookcases, File Cabinets, TVs, Carts*

Identify whether the following statements are true (T) or false (F).

(T) F 4.2 Shaking and displacement are the two primary causes of damage to nonstructural components.

T (F) 4.3 Anchorage and bracing for nonstructural components is typically designed by a structural engineer to resist seismic forces.
Anchorage for nonstructural components often does not occur, or is not an engineered solution. Often times the seismic design is delegated to the specific trade construction contractor to interpret, design and construct.

Section 5: Earthquake Performance Expectations for the Midwest

Identify whether the following statements are true (T) or false (F).

T (F) 5.1 Buildings tagged as Yellow or Green following an earthquake are completely safe for re-occupancy.
Restrictions are placed on the re-occupancy of buildings that are tagged as Yellow.

T (F) 5.2 Building code seismic design provisions are intended to prevent earthquake damage and property loss.
Building code provisions are intended to provide life safety and do not prevent damage or property loss.

Section 6: Overview of Seismic Risk Reduction

6.1 Match each of the following seismic risk reduction techniques with their relative costs and risks.

Do Nothing	High Cost, Low Risk
Replace	Continuous Use, Lower Cost
Rehabilitate	No Cost, High Risk
Incremental	Loss of Use, High Cost

Section 7: Planning and Managing the Process of Seismic Risk Reduction

Identify whether the following statements are true (T) or false (F).

(T) F 7.1 Planning for seismic performance of new facilities should include a dedicated effort to determine the level of earthquake performance desired for the facility.

T (F) 7.2 An effective risk reduction policy does not need to establish seismic performance objectives.

(T) F 7.3 Nonstructural mitigation of many components can be easily incorporated into existing maintenance programs.

T (F) 7.4 Incremental seismic strengthening is not recommended when one floor of a wing is undergoing remodeling/renovation as the other floors of the wing have not been seismically addressed.
Any time a space is scheduled for remodeling or renovation, there is an opportunity to also design and construct seismic strengthening improvements for both the building structure and nonstructural equipment, components, and systems within the space. It is the most cost-effective mitigation that can be performed.

Section 8: Structural Mitigation

Identify whether the following statements are true (T) or false (F).

(T) F 8.1 Seismic mitigation of buildings is most cost effective or economical if addressed when earthquake provisions are incorporated into the design and construction of a new facility.

T (F) 8.2 Seismic mitigation is often not feasible for hospital facilities because of the interruption – noisy, dirty, no swing space for relocation nature of structural strengthening.
While these are elements of construction, they are manageable if properly planned through an incremental mitigation program.

Section 9: Nonstructural Mitigation
Identify whether the following statement is true (T) or false (F).

T (F) 9.1 Nonstructural mitigation is only recommended for items that pose a life safety hazard.
Hospitals contain a vast array of nonstructural components that both support a clean environment for patients and staff as well as for performing medical activities, such that nearly all nonstructural components in a hospital would require functionality following a major earthquake event.

Identify the best retrofit strategy for each of the following nonstructural components:

9.2 Tall bookcases that are located in a primary egress corridor that are unrestrained and can possibly overturn and obstruct egress.

a. Ignore the problem because large ground motion is unlikely to occur.

b. Anchor the top of the bookcase to the adjacent wall to prevent overturning.

(c.) Relocate the bookcases from the corridor.

9.3 Emergency generator and the fuel oil day tank are sitting directly on a concrete equipment pad. Neither is anchored.

a. Install non-seismic vibration isolators to provide flexibility.

b. Install chains across the generator to restrict movement. Leave day tank unanchored.

(c.) Hire qualified seismic engineer and contractor to design and install the restraints for the generator and the day tank due to the critical nature of each.

9.4 Automatic transfer switch is located in an unoccupied basement mechanical room. The cabinet is tall and narrow and has no anchorage.

a. Anchorage is not required because the basement is unoccupied. Therefore there is no life safety hazard.

(b.) Install base anchorage for the cabinet to prevent overturning.

c. Install a chain around the cabinet to the nearest partition wall to limit how far it can move/rotate.

9.5 When should seismic mitigation activities be undertaken? (Circle all that apply)

(a.) During new construction

(b.) During remodeling/renovation of a room or area of a facility

(c.) During component or system replacement

Section 10: Integration Opportunities for Structural & Nonstructural Mitigation
Identify whether the following statements are true (T) or false (F).

(T) F 10.1 Nonstructural strengthening of architectural components integrates well into typical remodeling projects because ceilings, light fixtures, and walls are exposed and readily accessible.

T (F) 10.2 Nonstructural mitigation for cabinets, bookcases, and bench-top equipment should be designed by an engineering professional to ensure the adequacy of the seismic restraints.
Prescriptive designs are typically adequate and engineered solutions are not required for these types of nonstructural components.

(T) F 10.3 Hazardous material abatement projects provide opportunities for seismic strengthening because the areas are typically vacant and exposed for work.

FEMA P-767 CD, Earthquake Mitigation for Hospitals Workshop

Part 1 – Introduction

Workshop Overview

- Topics to be addressed today
  - Seismic safety improvements for hospitals
  - Seismic hazard and vulnerability
    - Structural
    - Non-structural
  - Process to reduce risk of earthquake damage
  - Structural and nonstructural mitigation
  - Integration opportunities for mitigation

Workshop Overview

- Workshop schedule
  - Presentations
  - Breaks
  - Lunch

Audience Characteristics

- Audience self introductions
- Questions for all: Is anyone:
    - Purchasing an existing facility?
    - Assessing your facilities?
    - Remodeling your facilities?
    - Constructing a new facility?

INTRODUCTION

Seismic Risk for Hospitals

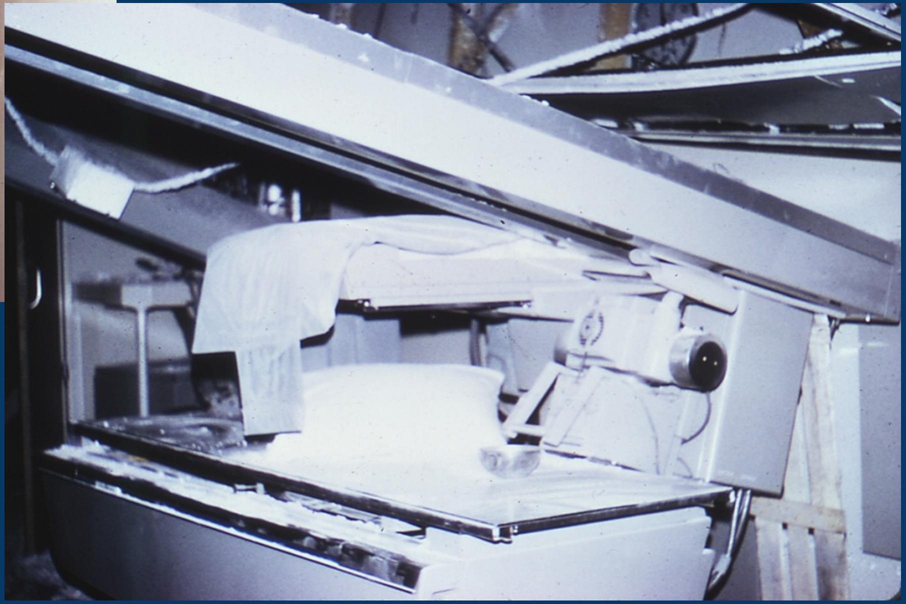
RISK = f (HAZARD, VULNERABILITY)

Risk is a function of both the potential hazard (seismic ground motion) and vulnerability (lack of seismic preparedness in structural and nonstructural systems)

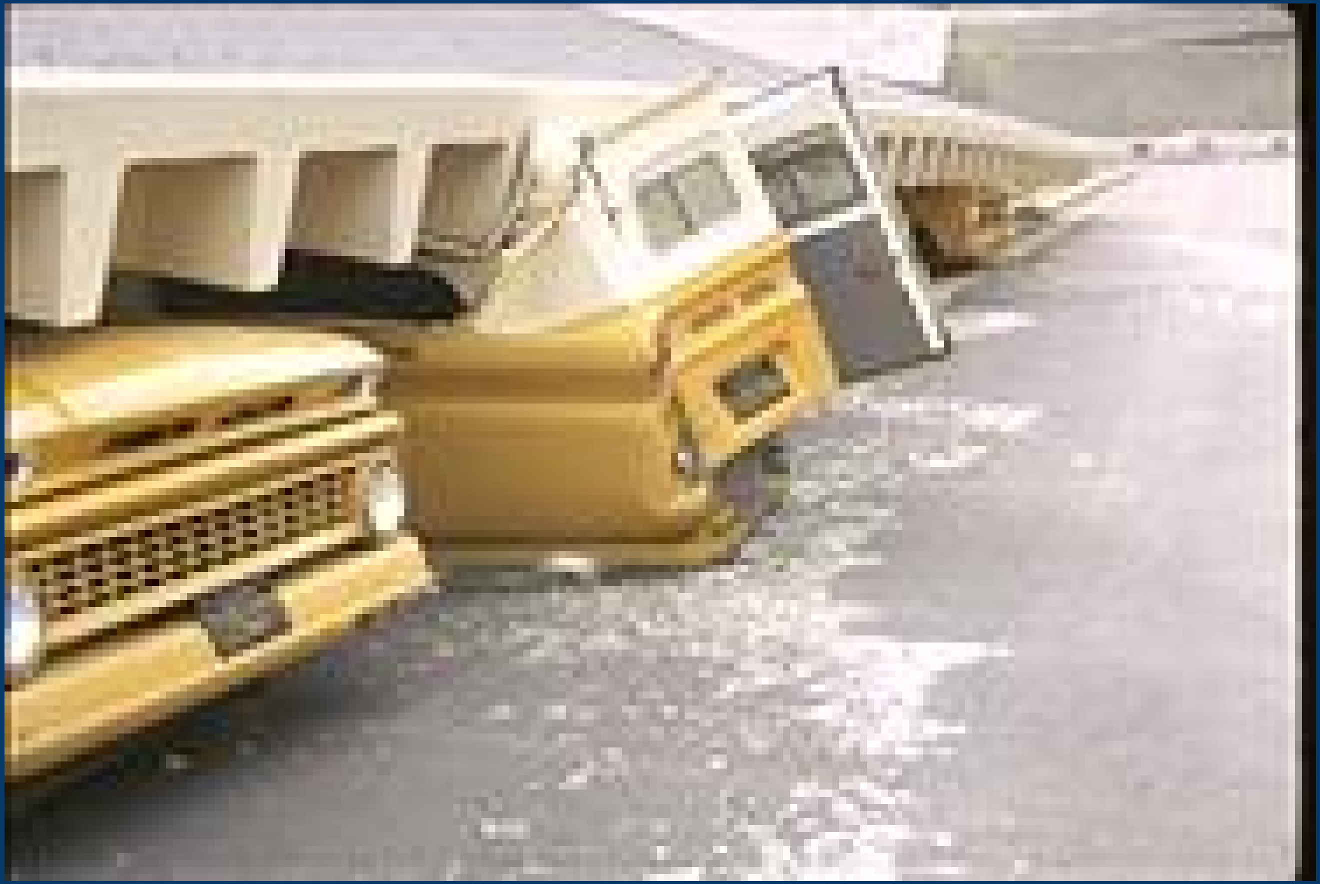
Deaths and Injuries of Staff and Patients

Collapse of Buildings or Parts of Buildings

Damage to Buildings, Equipment Furnishings and Contents



Disruption of Medical Service to Surge of Earthquake Victims



Long Term Disruption of Medical Services to Patients

Earthquake Hazard Overview

RISK = f (HAZARD, VULNERABILITY)

Photo Credits

- Degenkolb Engineers
- Lee, Burkhart, Liu Architects of Santa Monica
- URS Corporation (FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds*)
- Personal files of Mel Green, Mike Griffin, and Maryann Phipps, consultants to the Applied Technology Council

Earthquake Mitigation for Hospitals Workshop

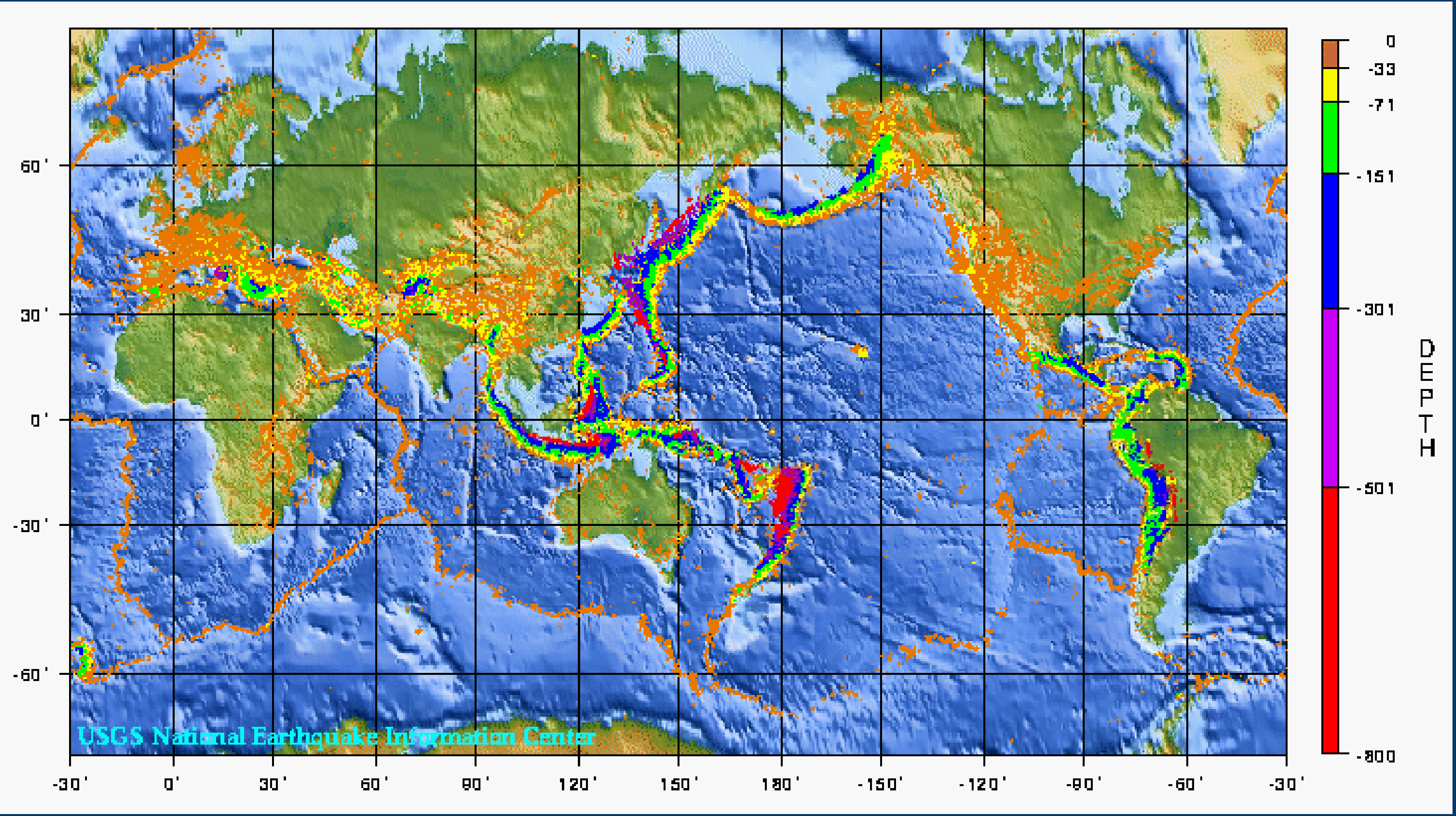
Part 2 – Earthquake Hazards

EARTHQUAKE HAZARD

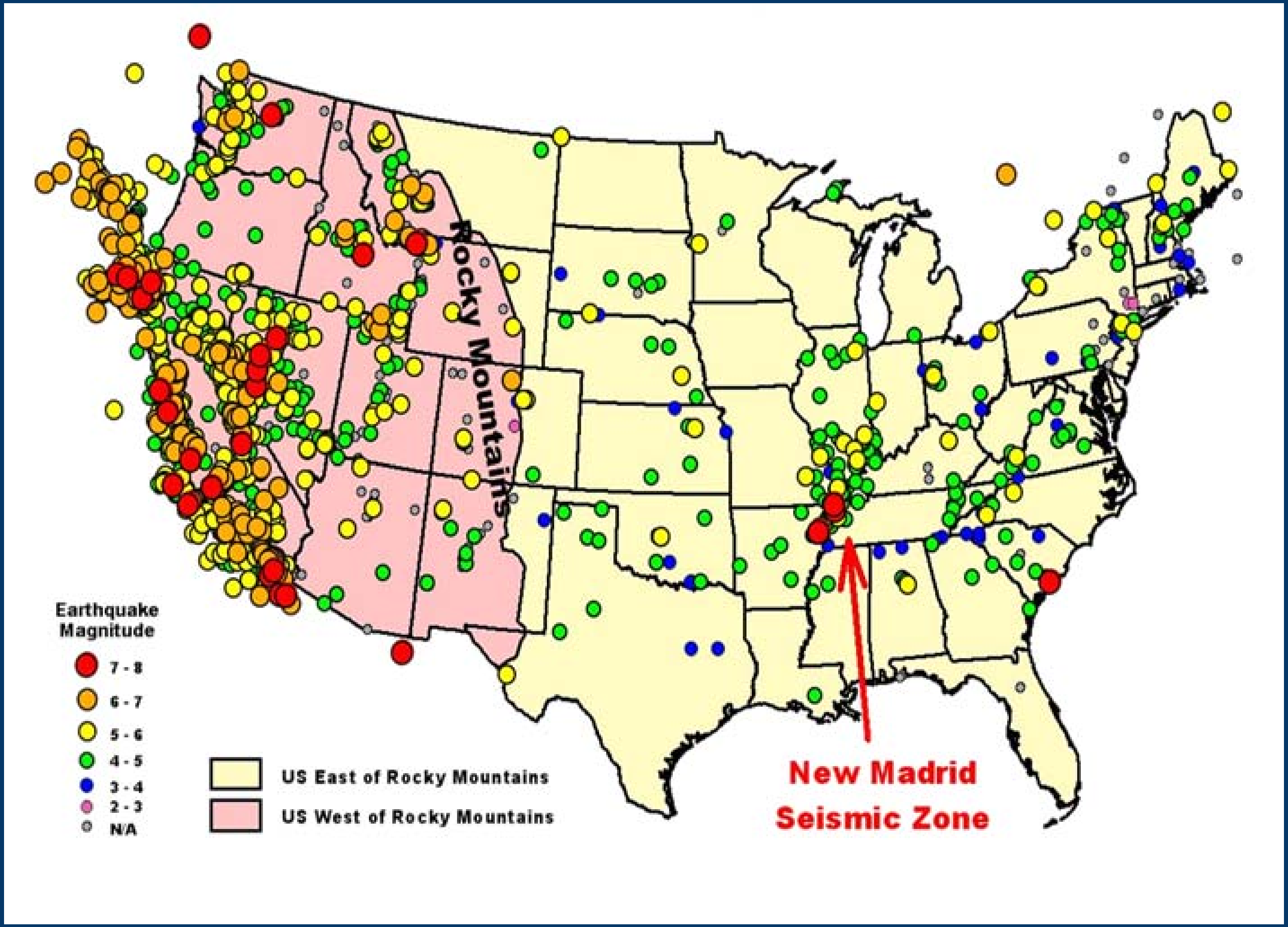
RISK = f(HAZARD, VULNERABILITY)

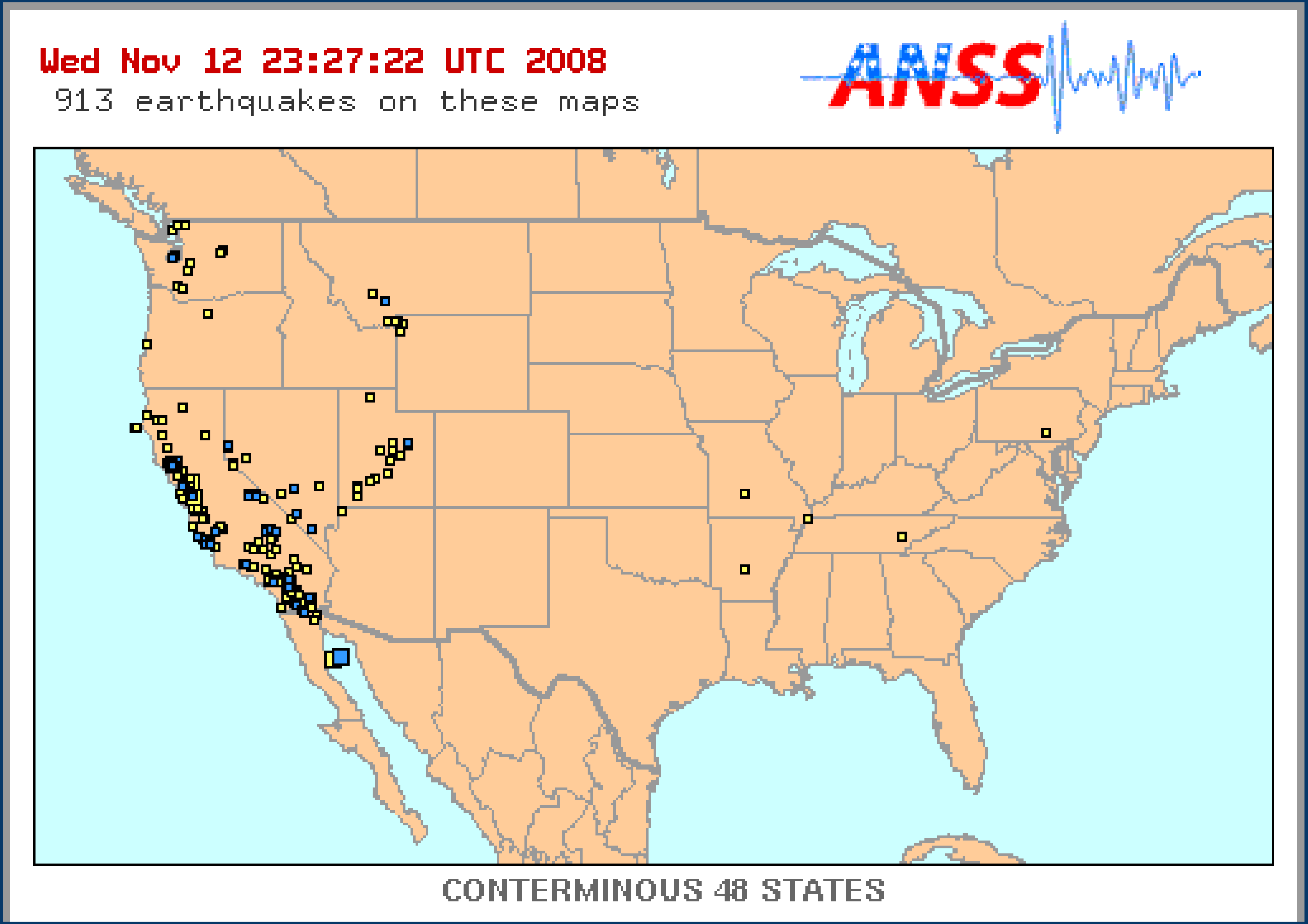
Risk is a function of both the potential hazard (seismic ground motion) and vulnerability (lack of seismic preparedness in structural and nonstructural systems)

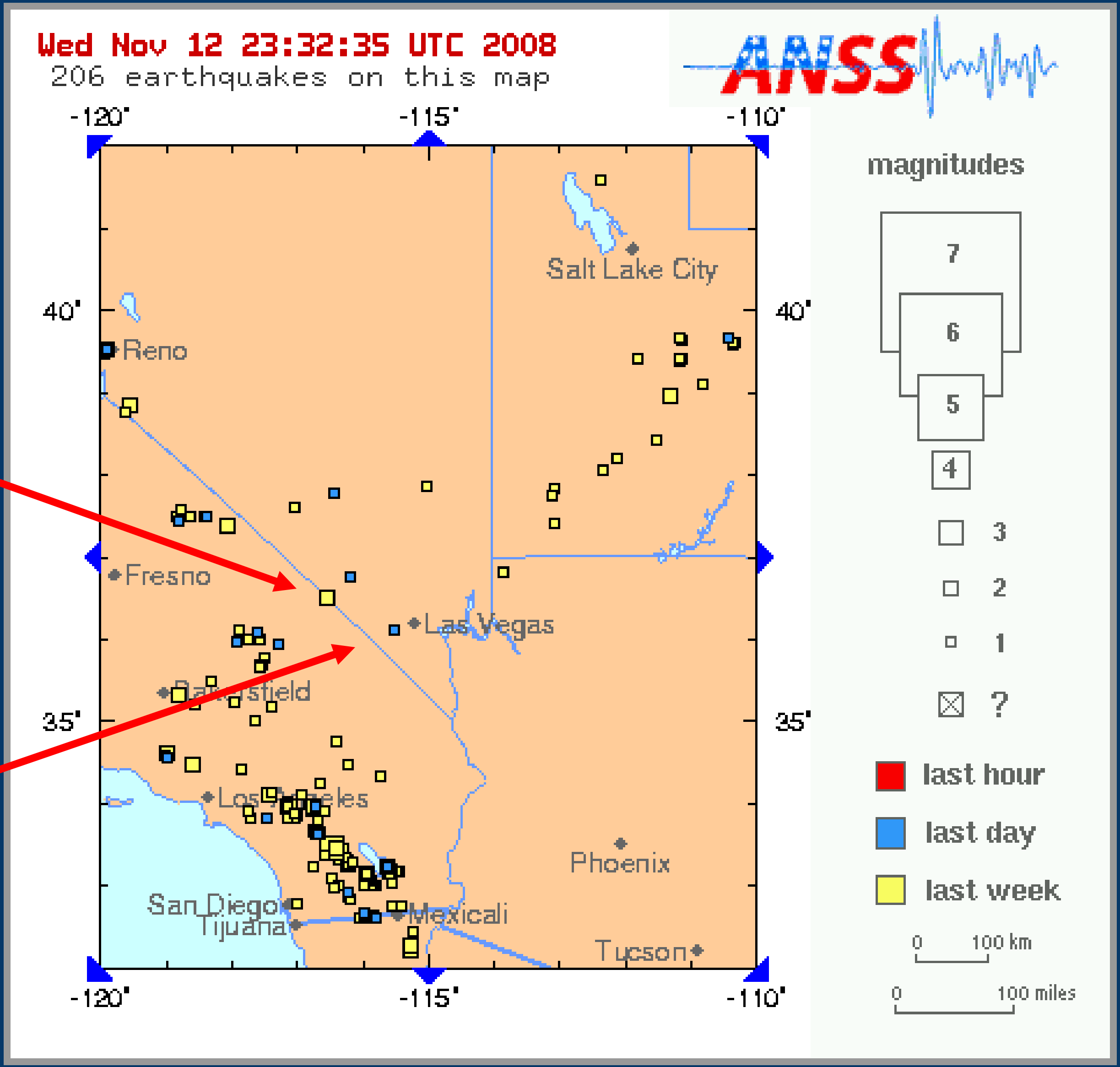
Plate Boundaries & Earthquakes



Historic Damaging Earthquakes

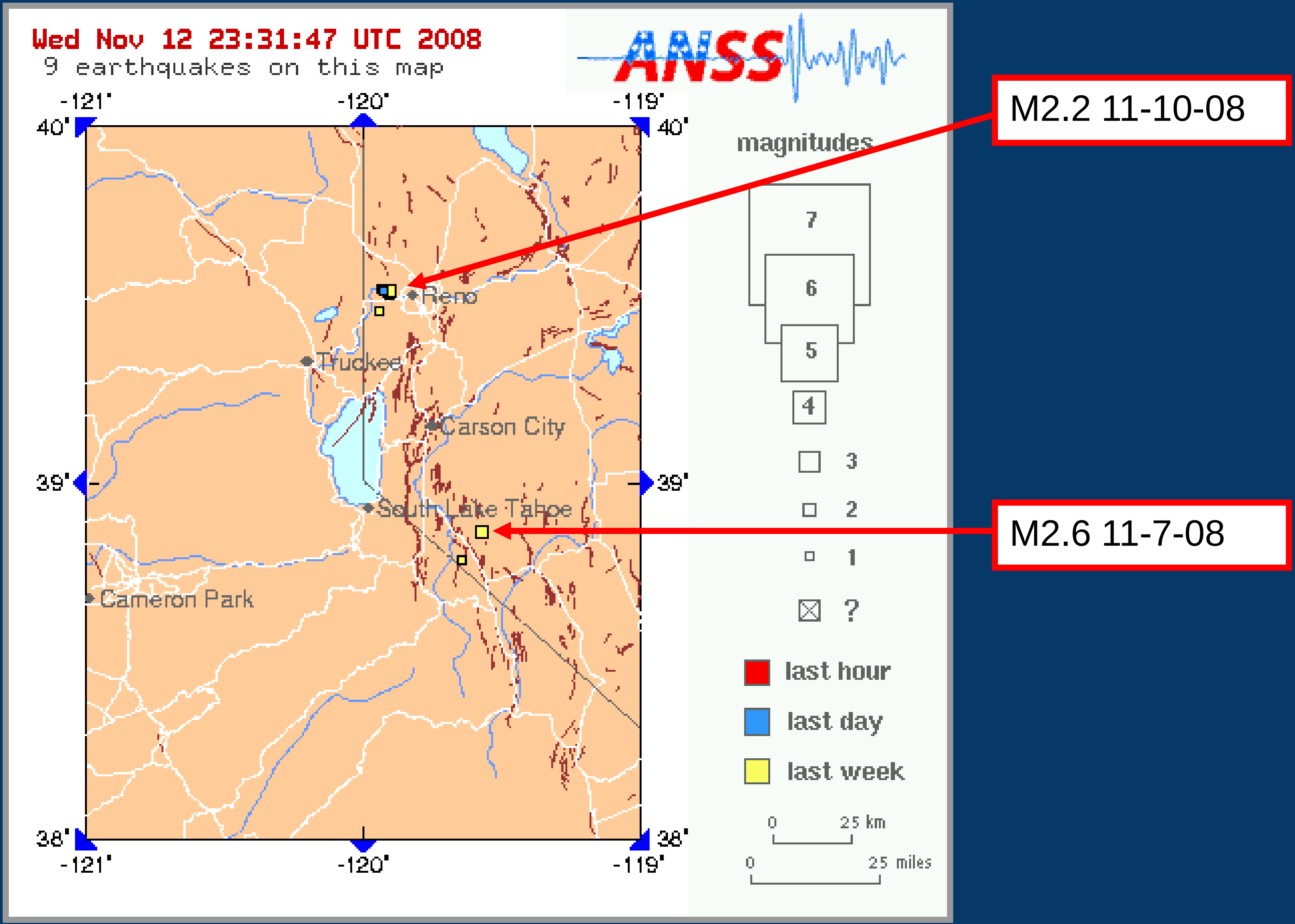


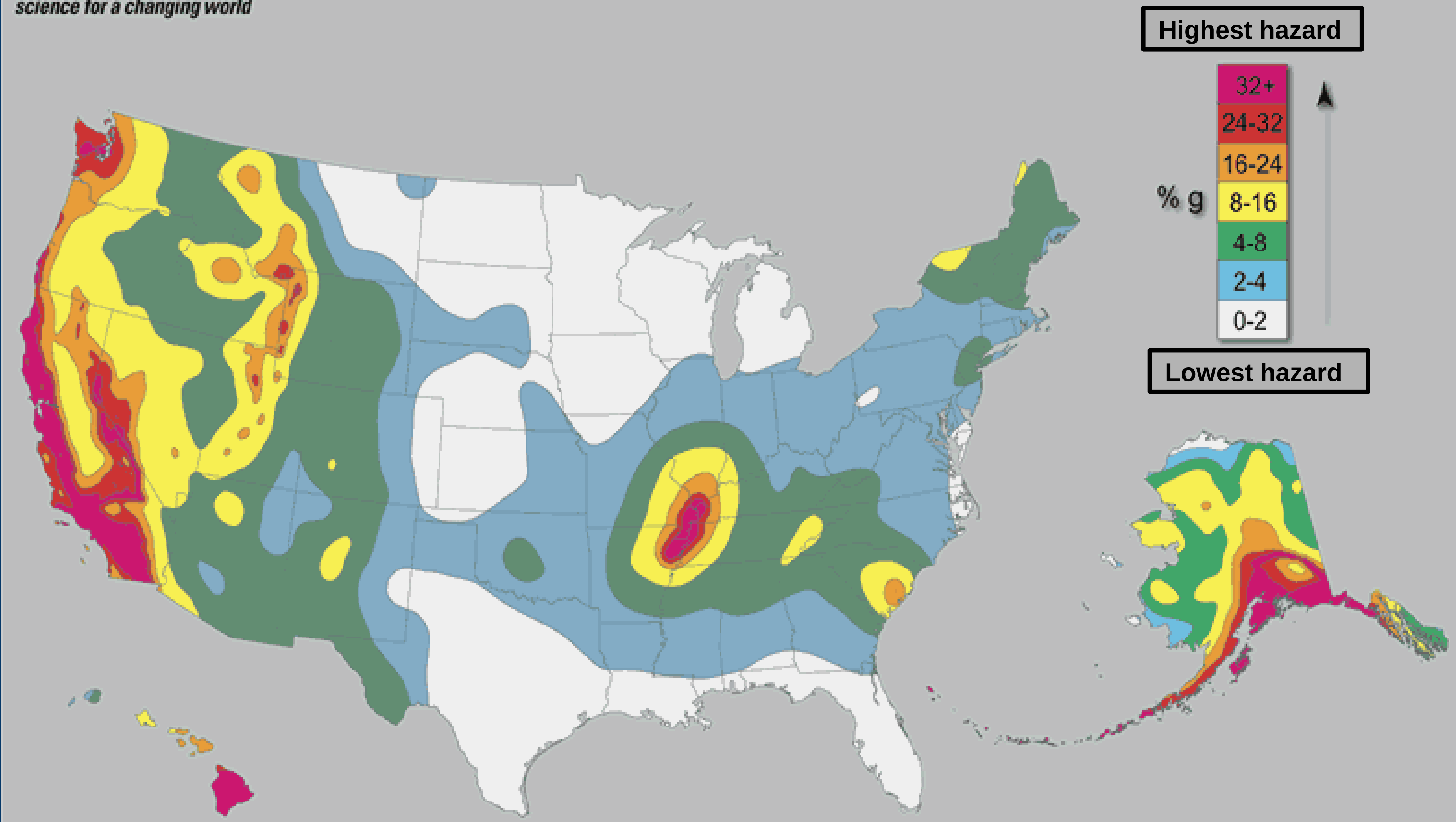

Wed Nov 12 23:27:22 UTC 2008
913 earthquakes on these maps
ANSS
CONTERMINOUS 48 STATES



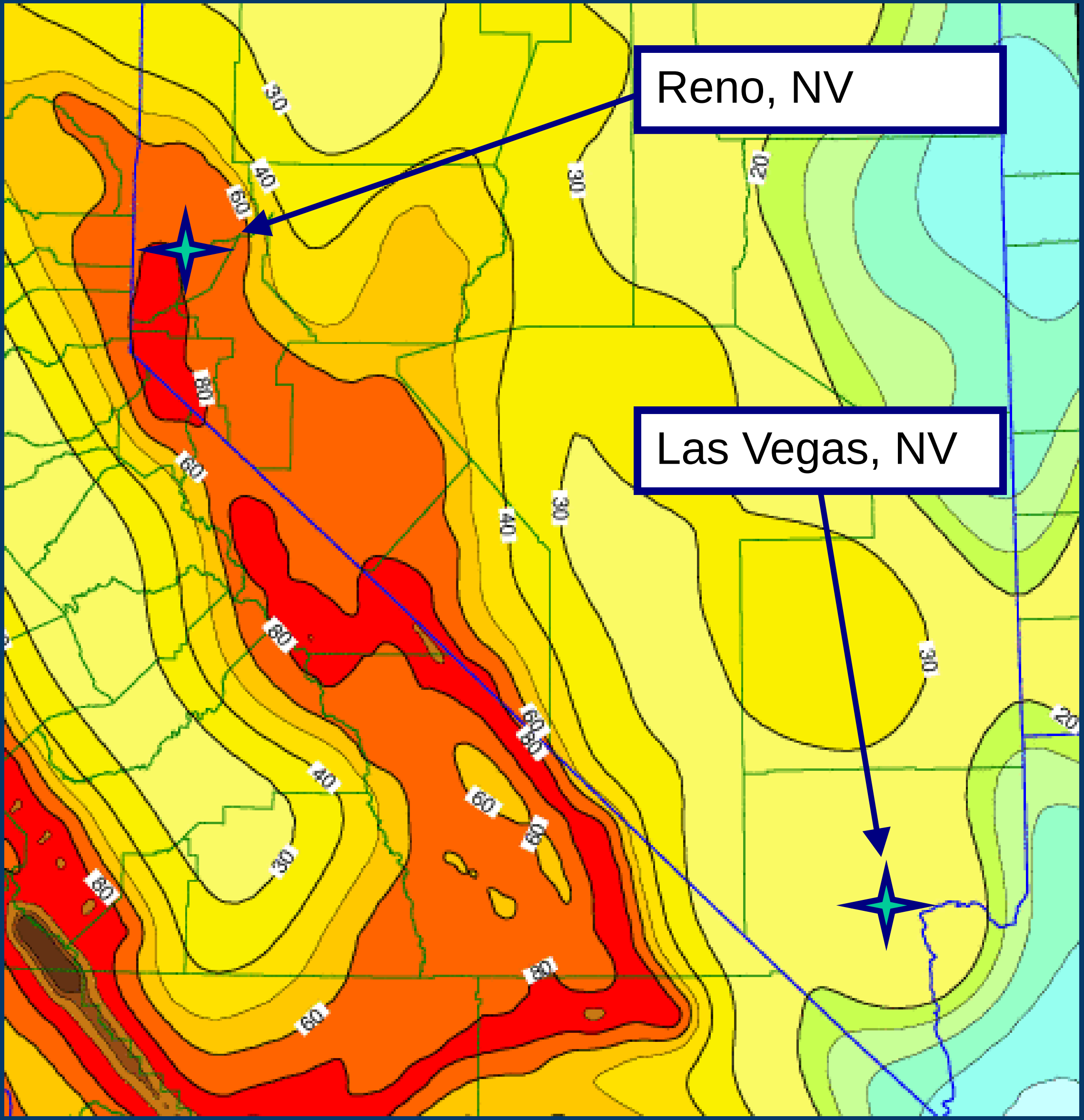
M2.3 11-8-08

M1.7 11-12-08


Wed Nov 12 23:31:47 UTC 2008
9 earthquakes on this map
ANSS
-121°
-120°
-119°
40°
39°
38°
Reno
Truckee
Carson City
South Lake Tahoe
Cameron Park
magnitudes
7
6
5
4
3
2
1
?
last hour
last day
last week
0 25 km
0 25 miles
M2.2 11-10-08
M2.6 11-7-08



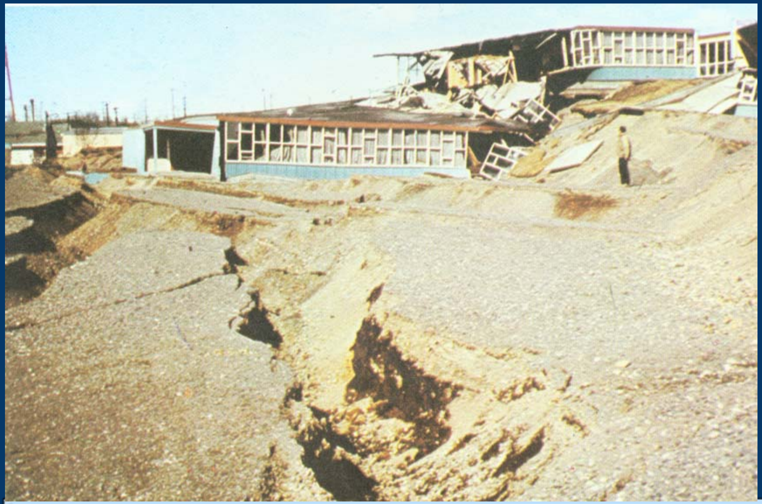
USGS
science for a changing world

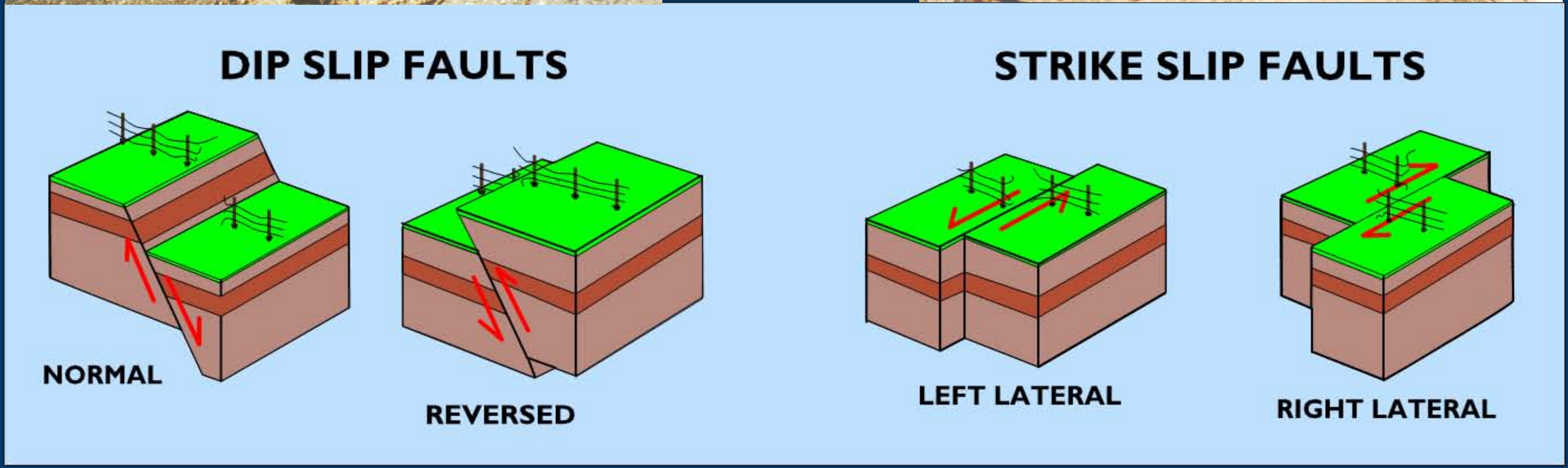

Reno, NV
Las Vegas, NV
30
40
60
80
20

Earthquake Hazards

- Fault rupture
- Ground shaking
- Settlement
- Landslides
- Liquefaction
- Tsunami

Faulting

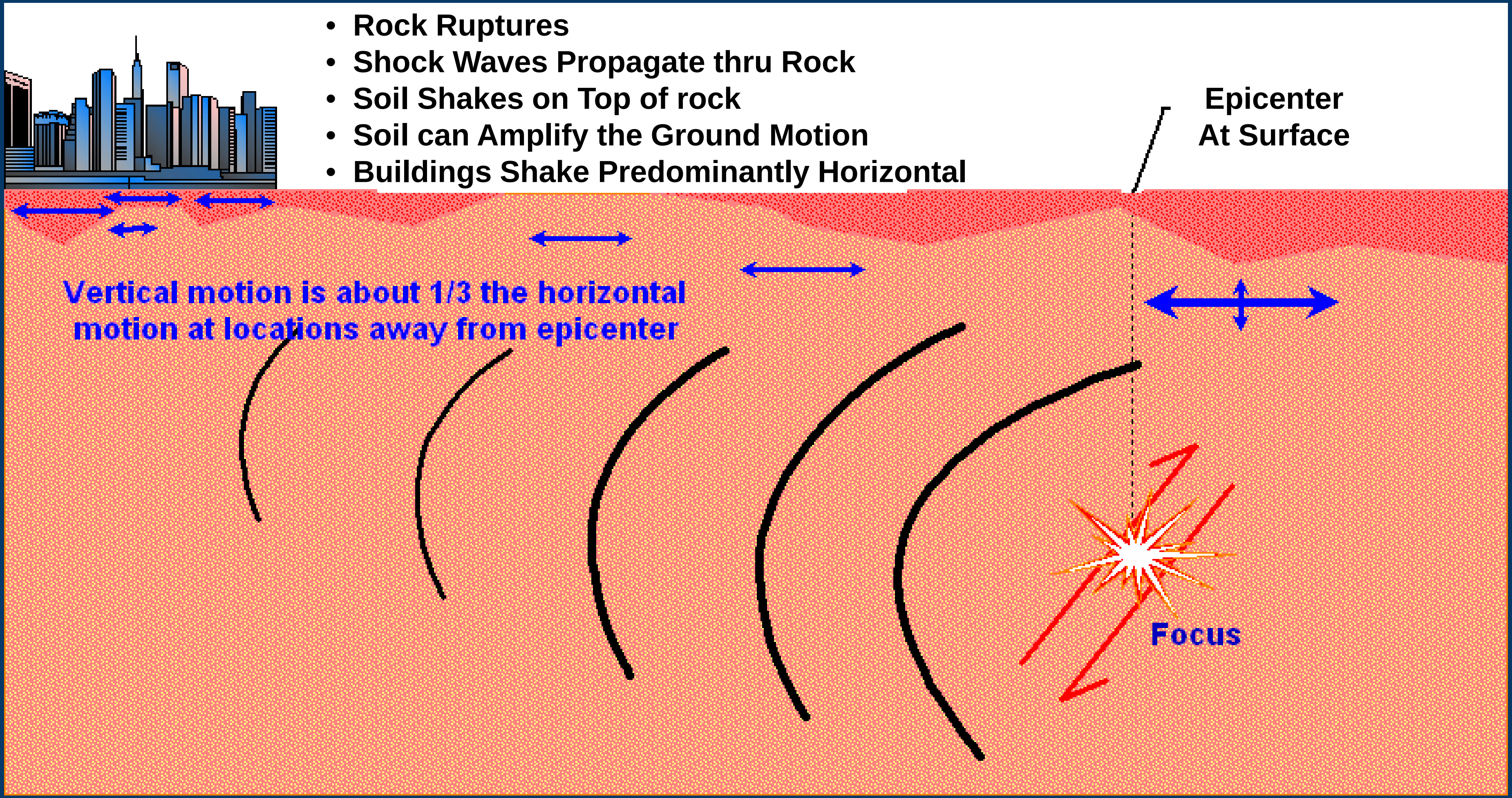




DIP SLIP FAULTS
STRIKE SLIP FAULTS
NORMAL
REVERSED
LEFT LATERAL
RIGHT LATERAL

Ground Shaking

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



Liquefaction

Questions?

Earthquake Mitigation for Hospitals Workshop

Part 3 – Structural Vulnerability

Building Structural Vulnerability to Earthquakes

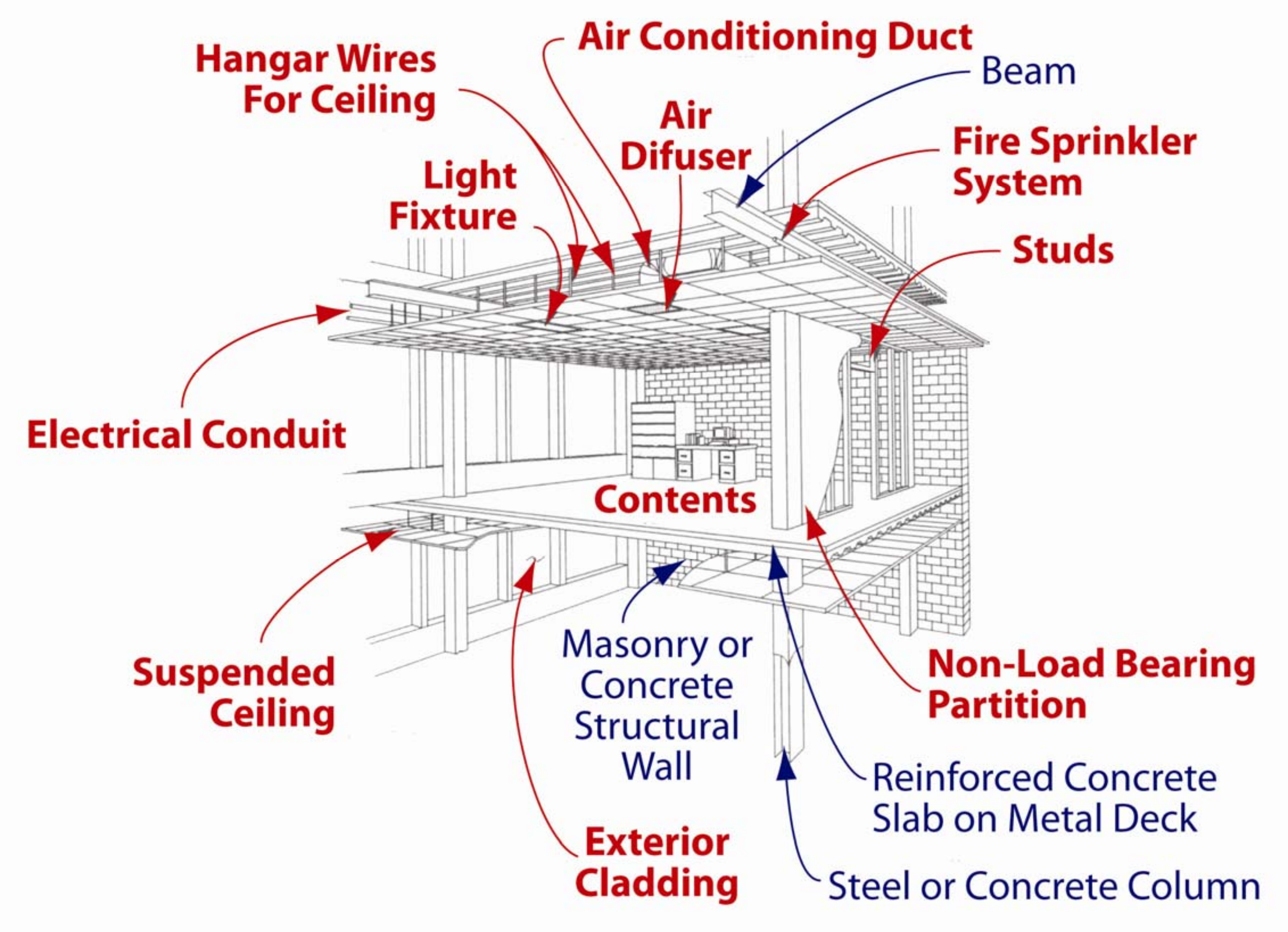
RISK = f(HAZARD, VULNERABILITY)

Risk is a function of both the potential hazard (seismic ground motion) and vulnerability (lack of seismic preparedness in structural and nonstructural systems)

Section Outline

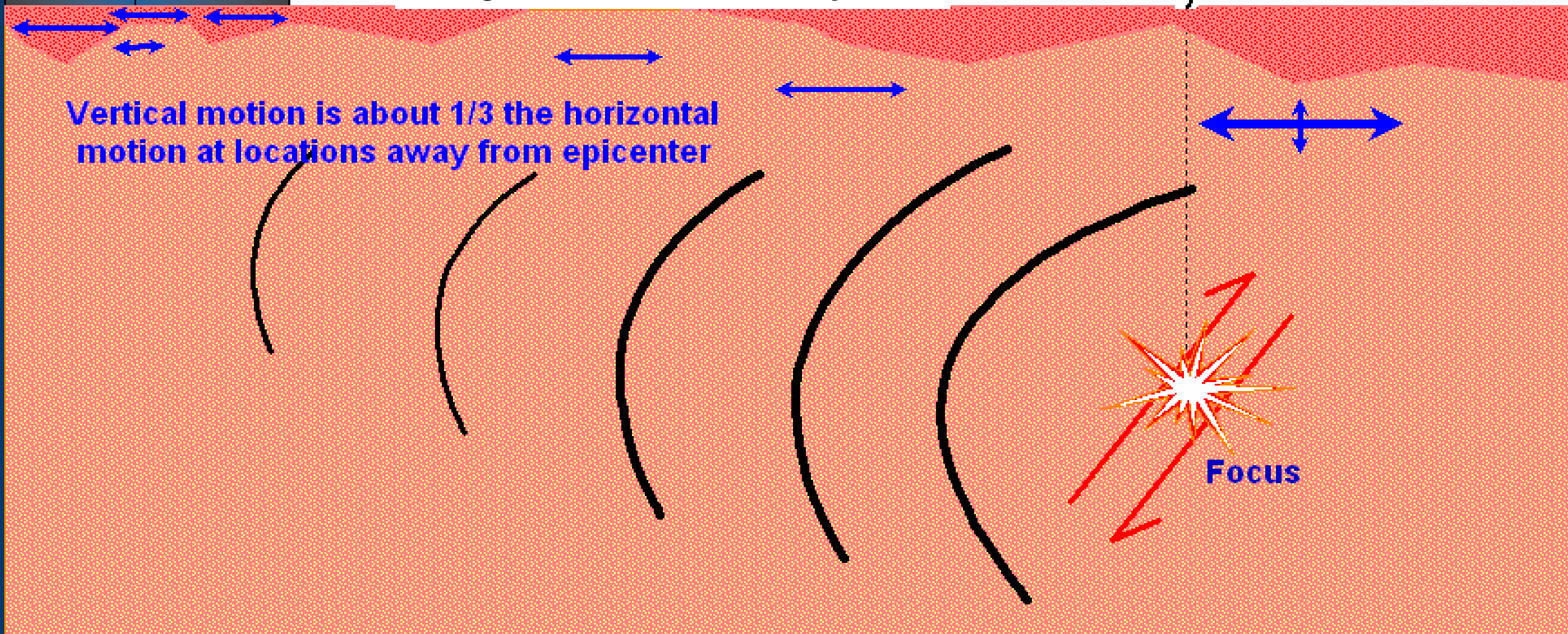
- Building response to earthquake ground shaking
- Effect of building type, age, configuration, regularity on performance
- Pounding between buildings
- Examples of structural damage
- Implications of building response to nonstructural performance

Structural & Nonstructural Components

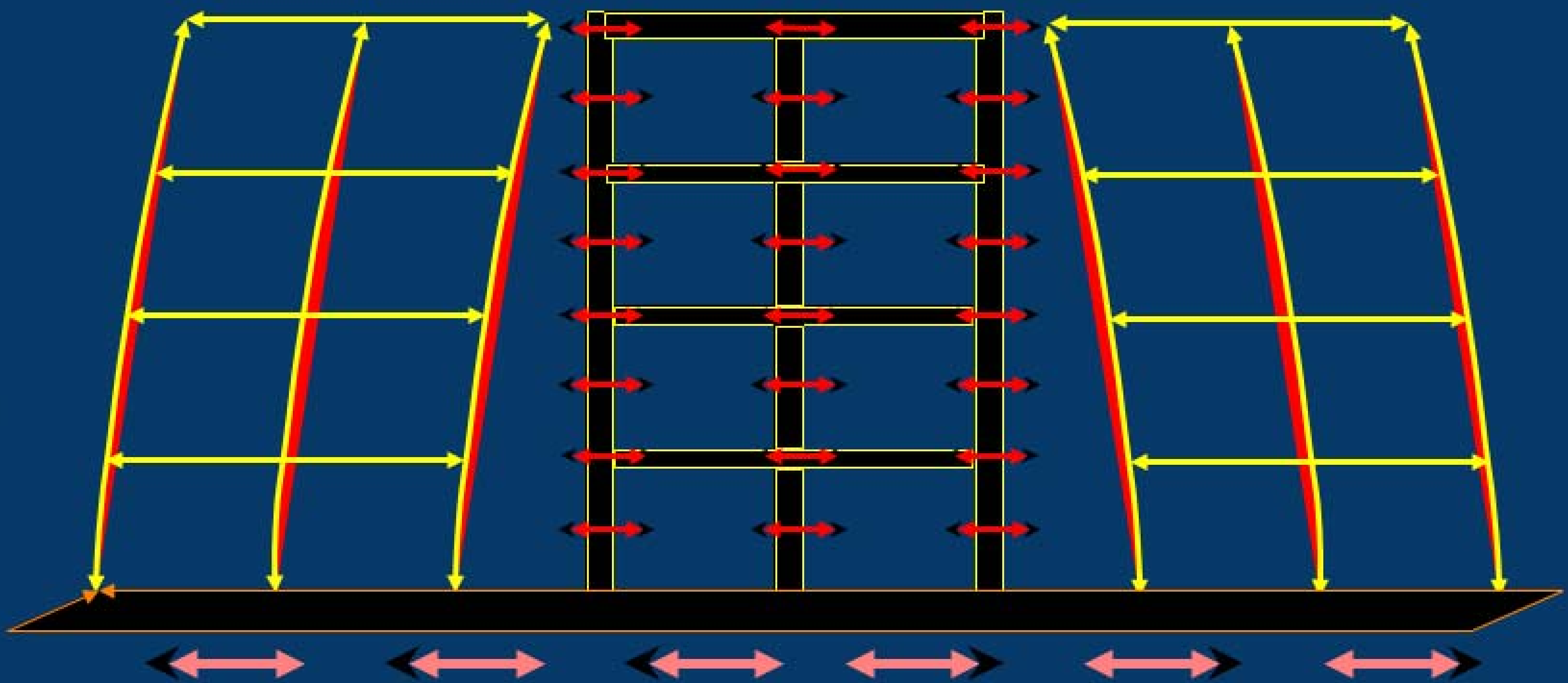


Building Response to Earthquake Ground Shaking

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

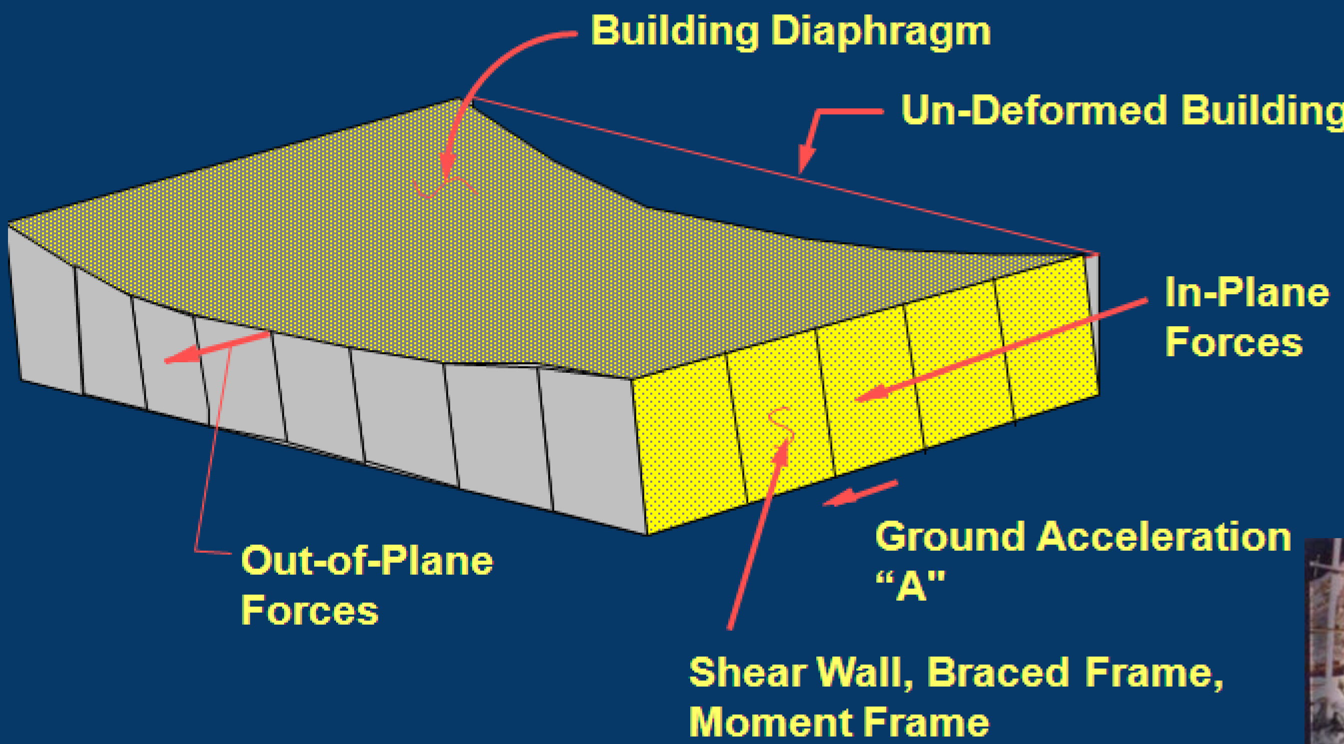


Earthquake Loads on Buildings

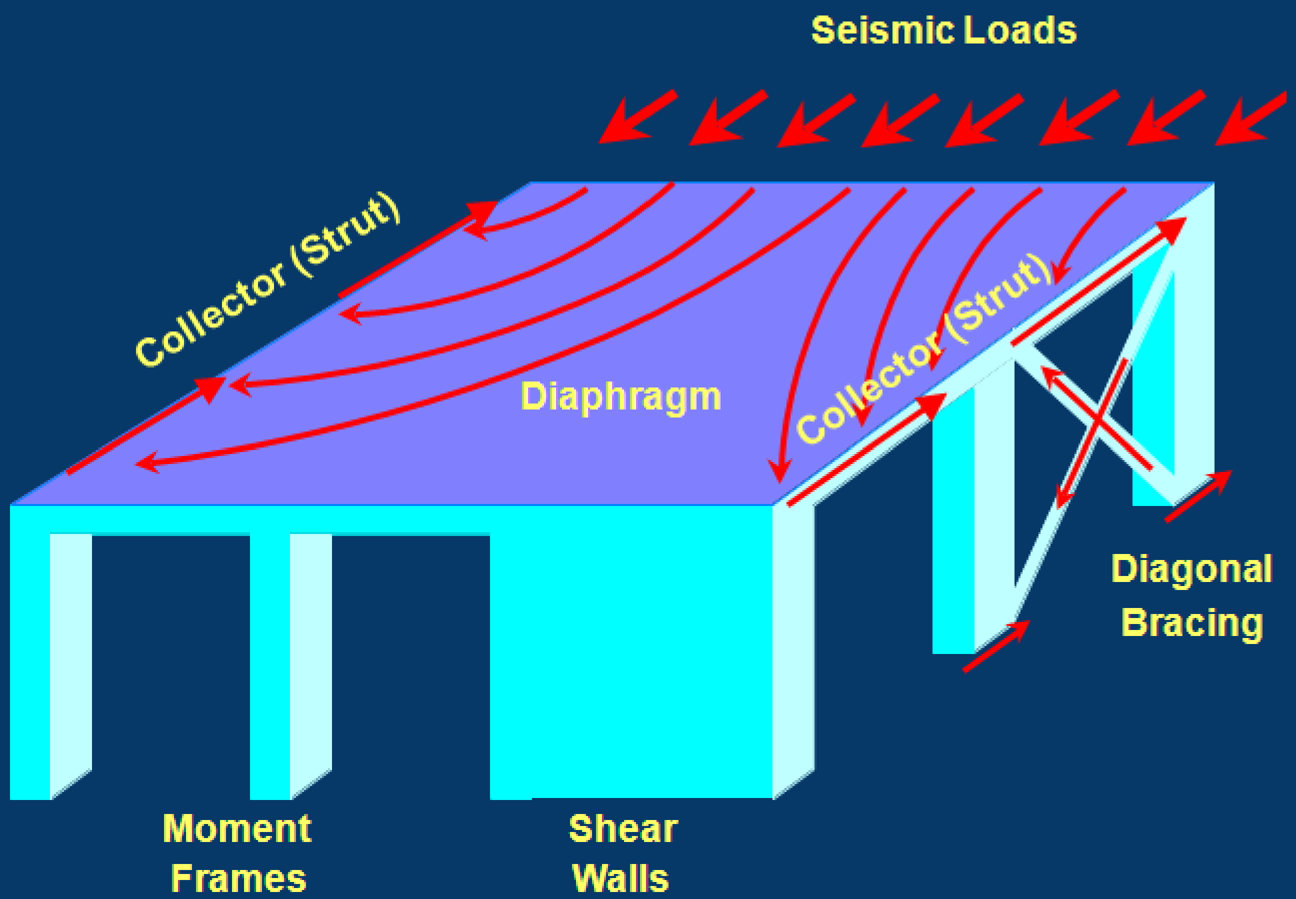


Ground Shakes Primarily In Both Horizontal Directions
Bottom Of Building Moves with Ground
Top Of Building Tries to Follow

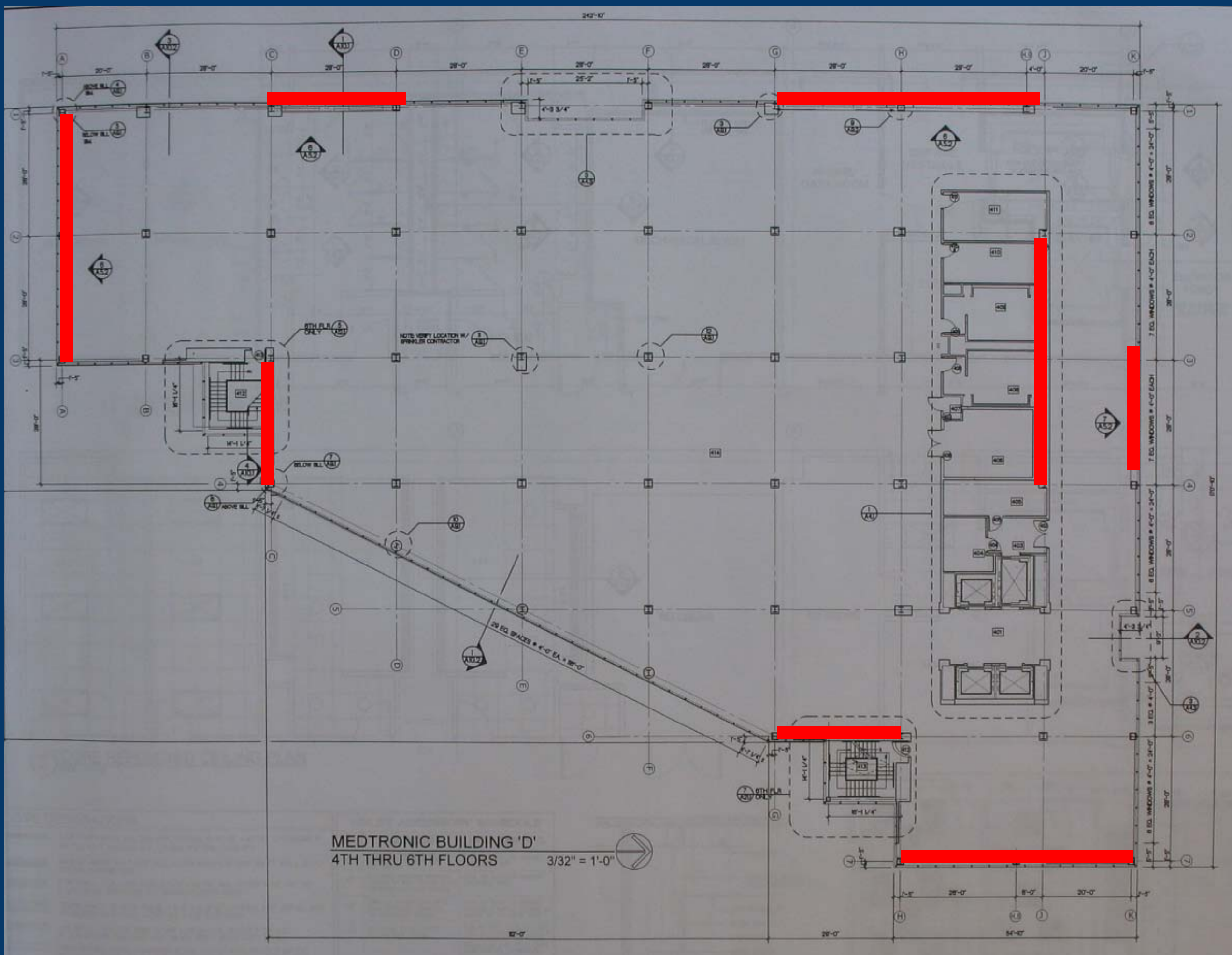
Earthquake Response of Structures

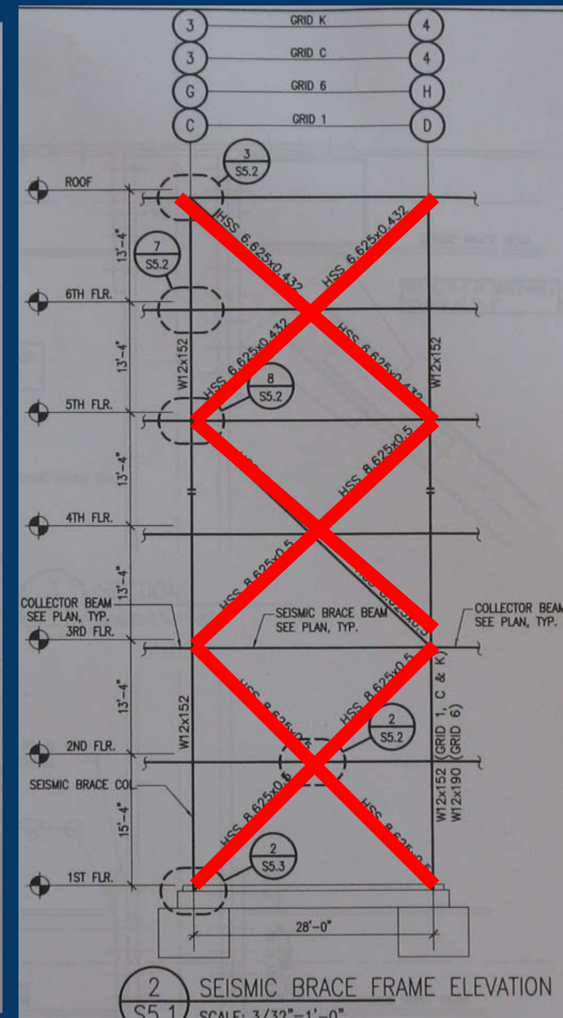


Building Lateral Force Resisting Systems – Key to Good Performance

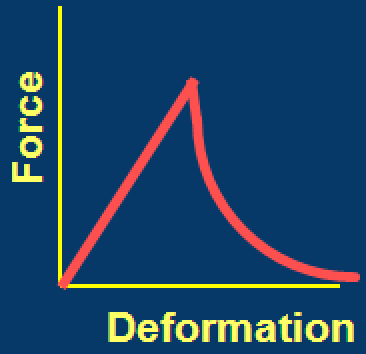


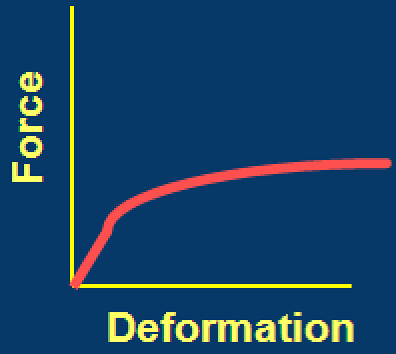
Lateral Force Resisting System

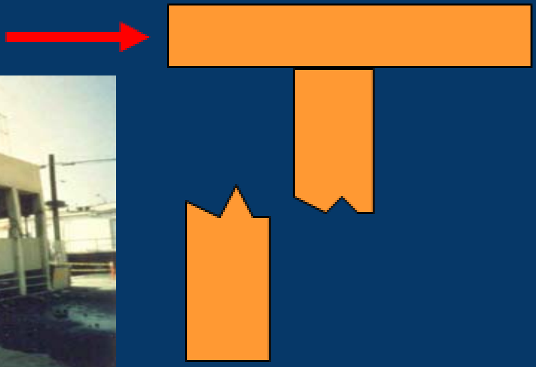


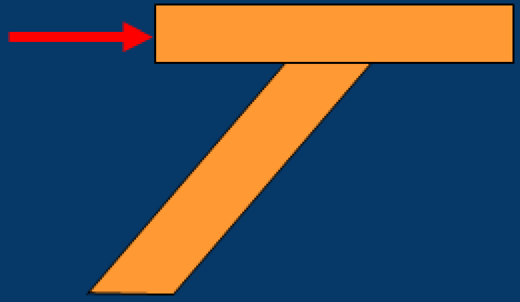


Strength & Ductility





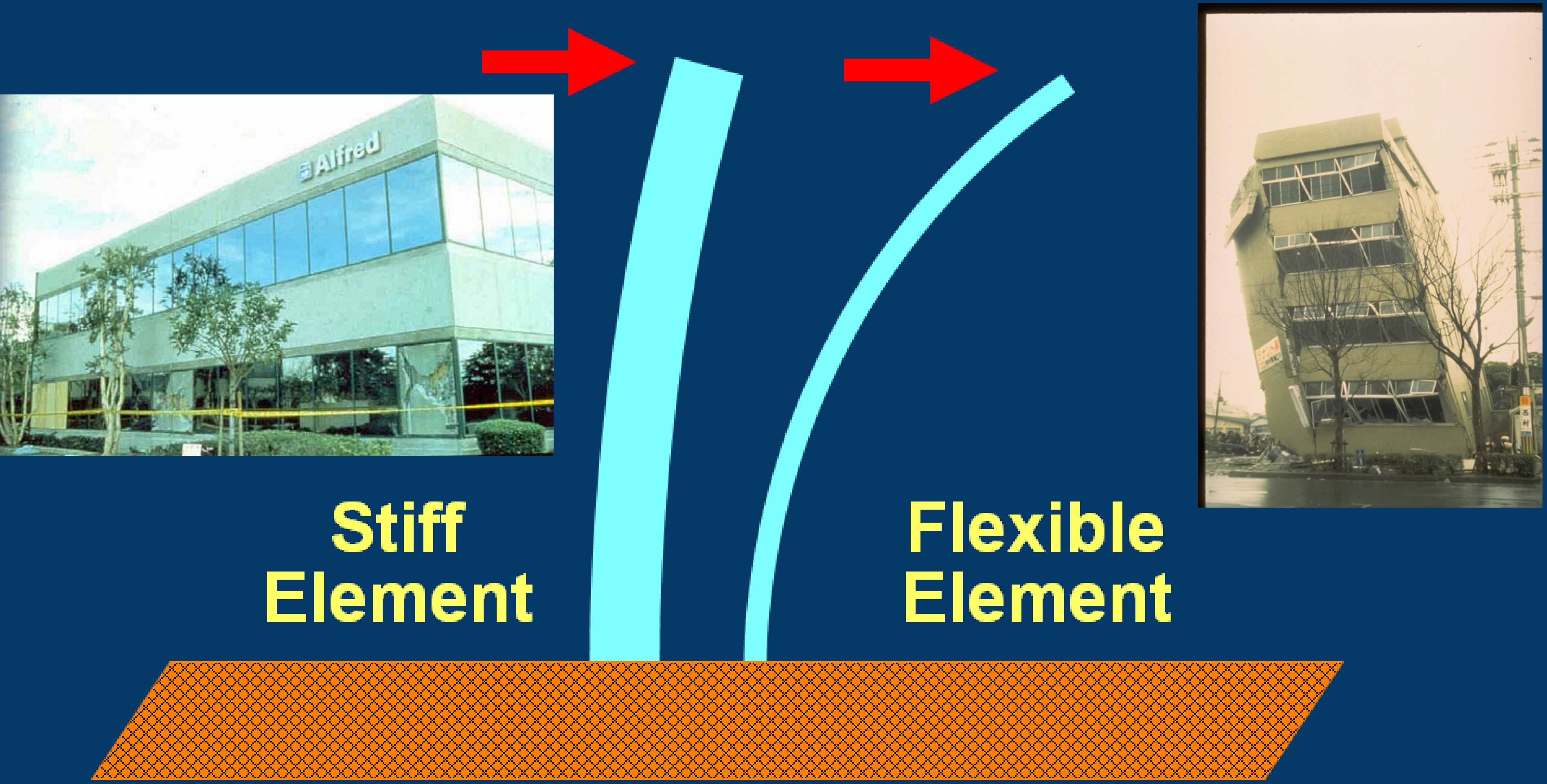




Analogy: Chalk

Rubber

Building Stiffness



Other Performance Predictors

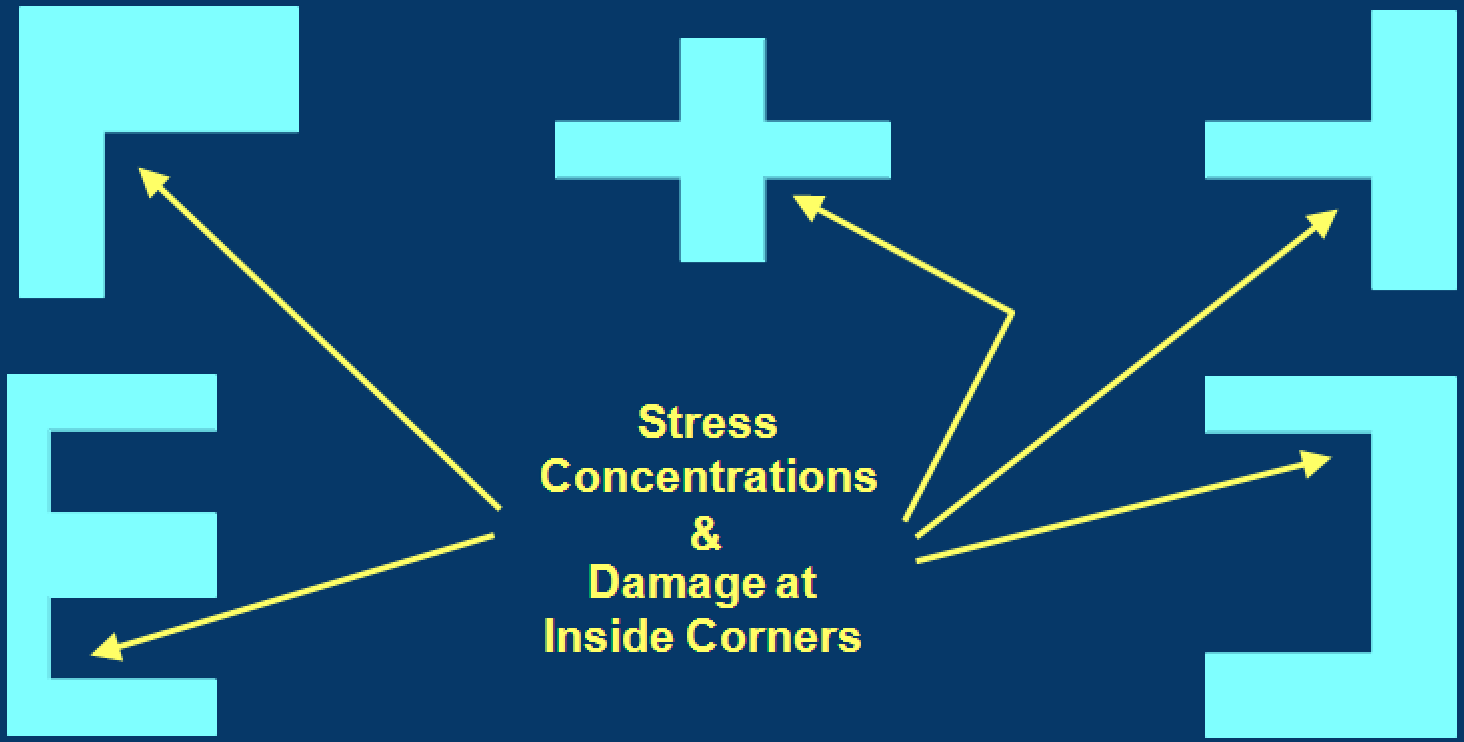
- Structure Type:
  - Unreinforced Masonry
  - Concrete Shear Wall
  - Concrete Frame
  - Concrete Frame with/ infill Shear Walls
  - Steel Frame
  - Steel Frame with/ infill Shear Walls
  - Steel Braced Frame
  - Precast Concrete Frame

Performance Predictors (Cont.)

- Building Age:
  - Governing building code (seismic design)
  - Seismic provisions enforcement
  - Materials used in construction
  - Advances in technology
  - Quality of construction
  - Deterioration with age

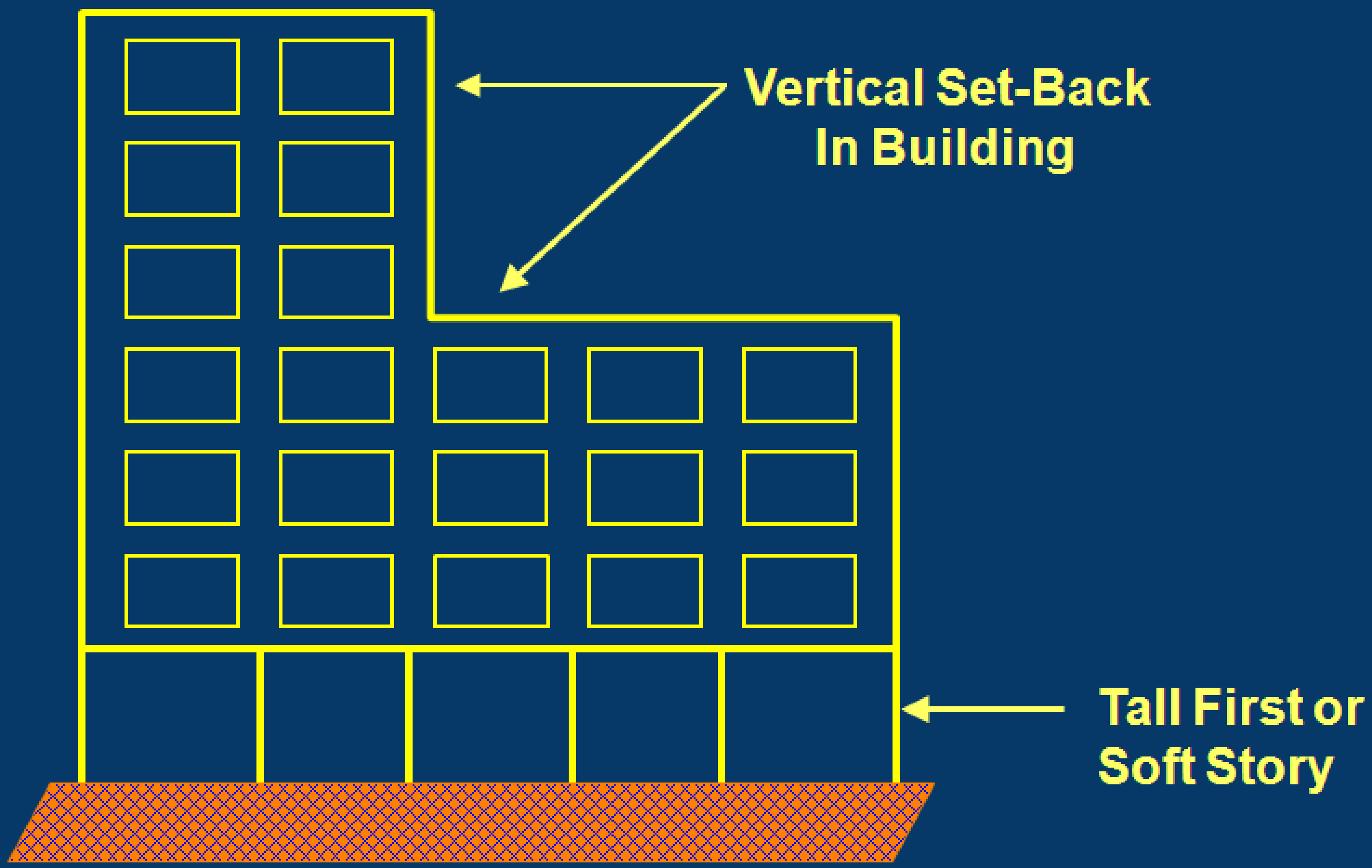
Performance Predictors (Cont.)

- Structure Configuration:
  - Plan irregularities



Plan Irregularities

Building Vertical Irregularities



Vertical Irregularities

Vertical Irregularities

Diaphragm Discontinuities

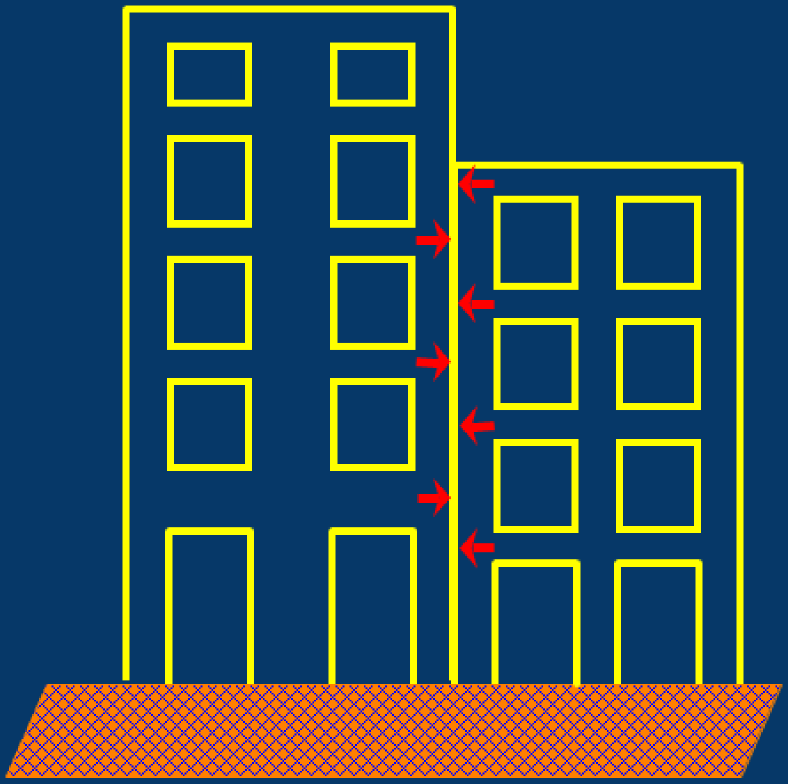
Stiffness Irregularity

- Soft Story:
  - Typically occurs at the first story
  - Desired architectural effect is tall open lobby or entry areas
  - Story stiffness significantly different than adjacent stories

Soft Story

Building Adjacency (Pounding)

- Inadequate building separation
- Floors & roofs do not align



Building Pounding

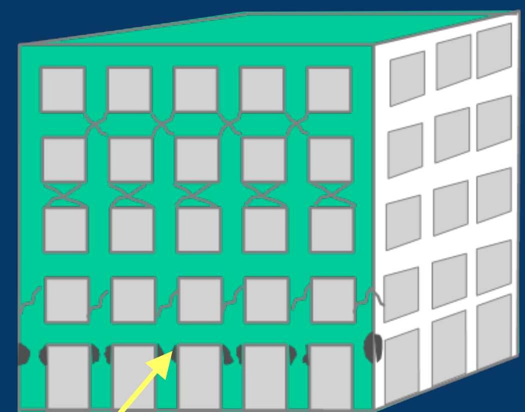
Building Differential Displacement

Building Damage

Unreinforced Masonry Building Damage

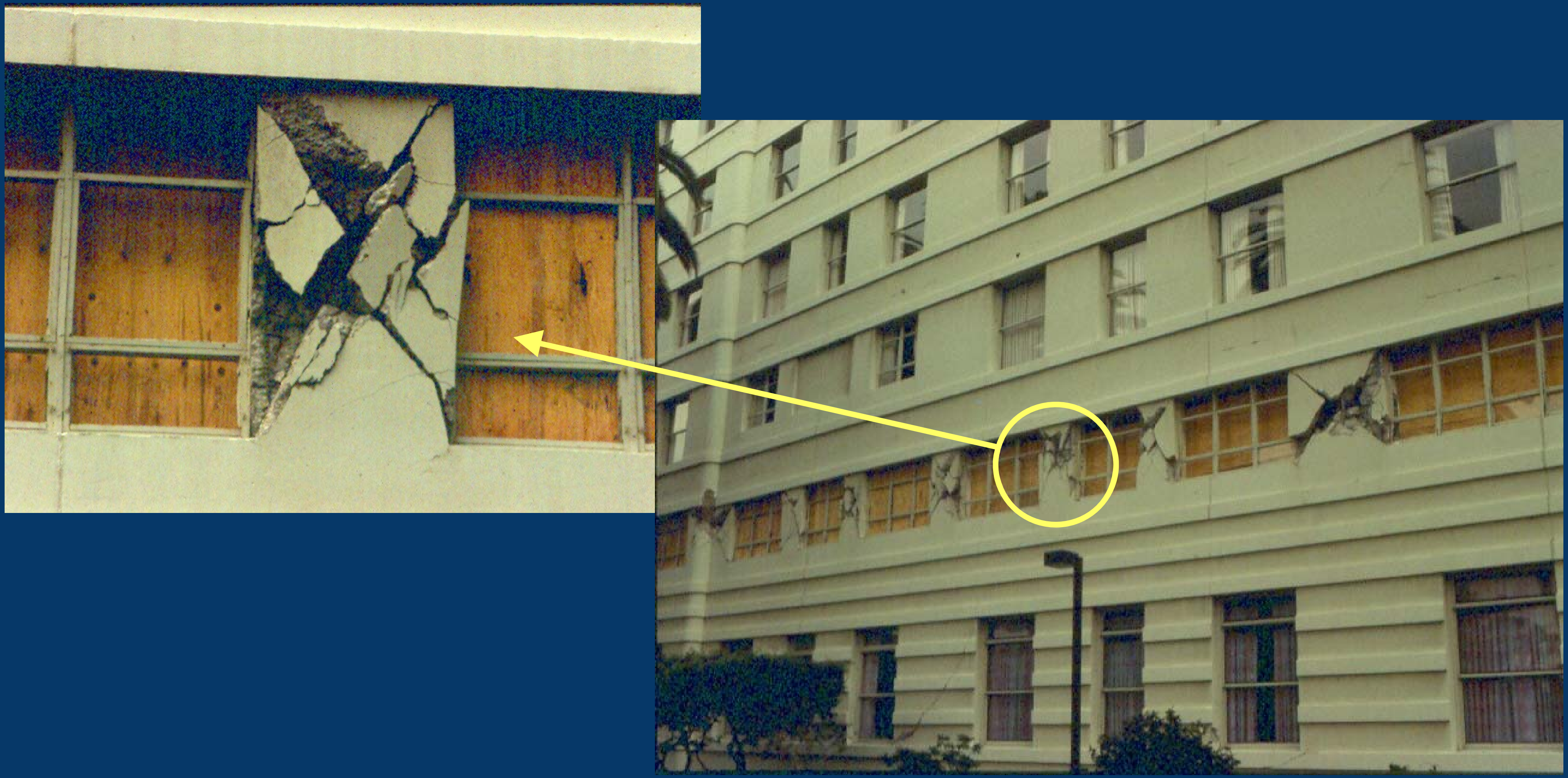
Unreinforced Masonry Damage

Concrete Frame Building Damage



Typical "X" cracking patterns

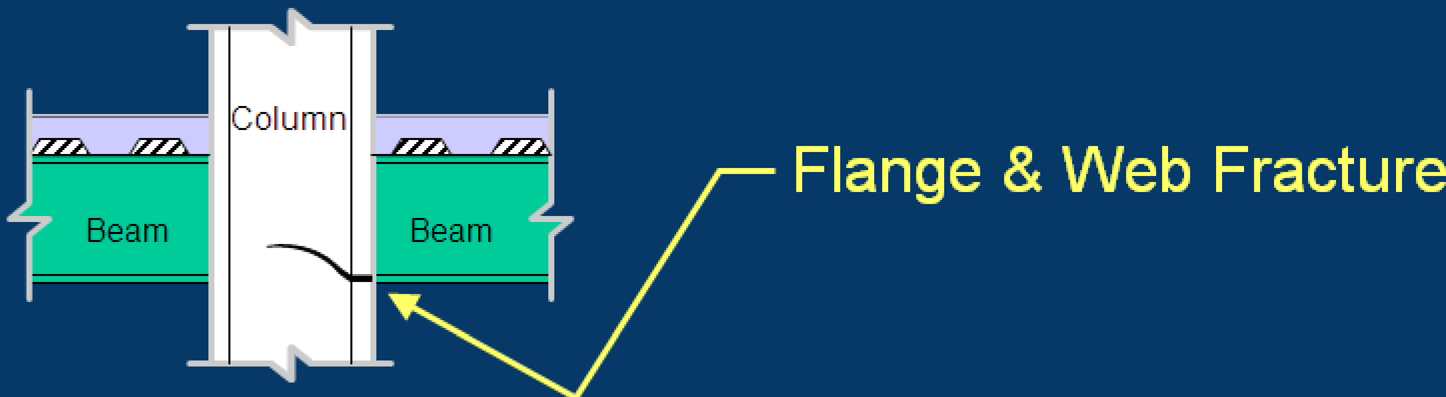
Concrete Frame Building Damage



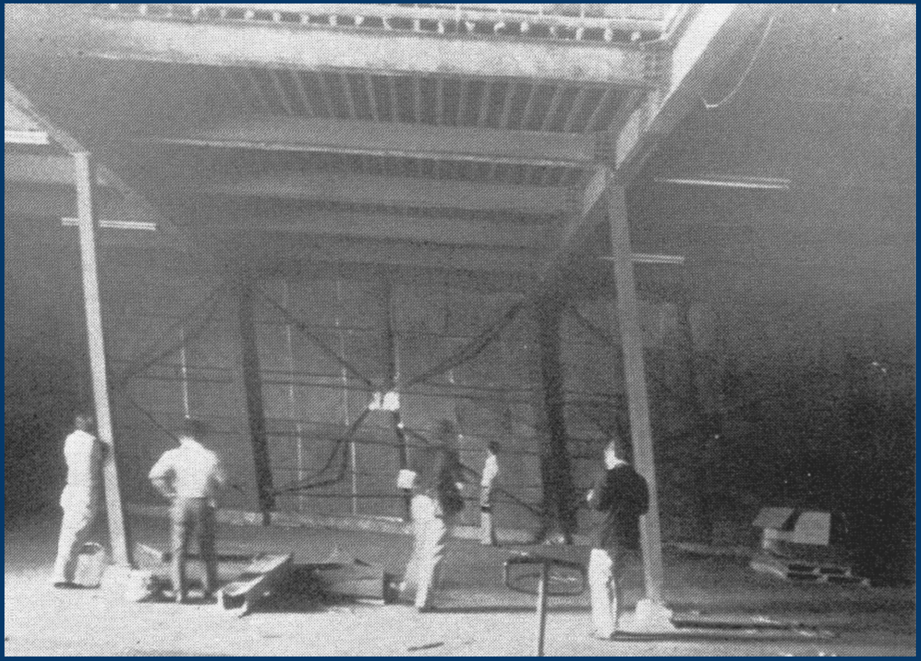
Concrete Frame Building Damage

Concrete Frame – Olive View Hospital

Steel Frame Building Damage



Steel Frame Building Damage



Precast Concrete Frame Damage

Building Pounding Damage

Building Damage can be Subtle

Generalized Building Structure Earthquake Performance

Decreasing Vulnerability ↓

Stiff Structures	Flexible Structures
Unreinforced Masonry (Brick)	Concrete Precast Frame (Parking Garages)
Concrete Frame with URM Infill	Concrete Moment Resisting Frames
Concrete Tilt-Up	
Steel Frame w/URM Infill Shear Walls	
Reinforced Masonry	Steel Moment Resisting Frames
Concrete Shear Wall	Light Metal Frame Buildings
Steel Braced Frames	Wood Frame Buildings

Implications of Building Response on Nonstructural Component Performance

- Nonstructural Performance Dependent upon:
  - Level of ground shaking
  - Response of the building structure
  - Flexibility or stiffness of the building structure
  - Seismic design and detailing of nonstructural components, equipment, & systems; e.g., are the seismic restraints compatible with expected building response – stiff or flexible building structure?

PLAY SHAKE TABLE VIDEO

Earthquake Mitigation for Hospitals Workshop

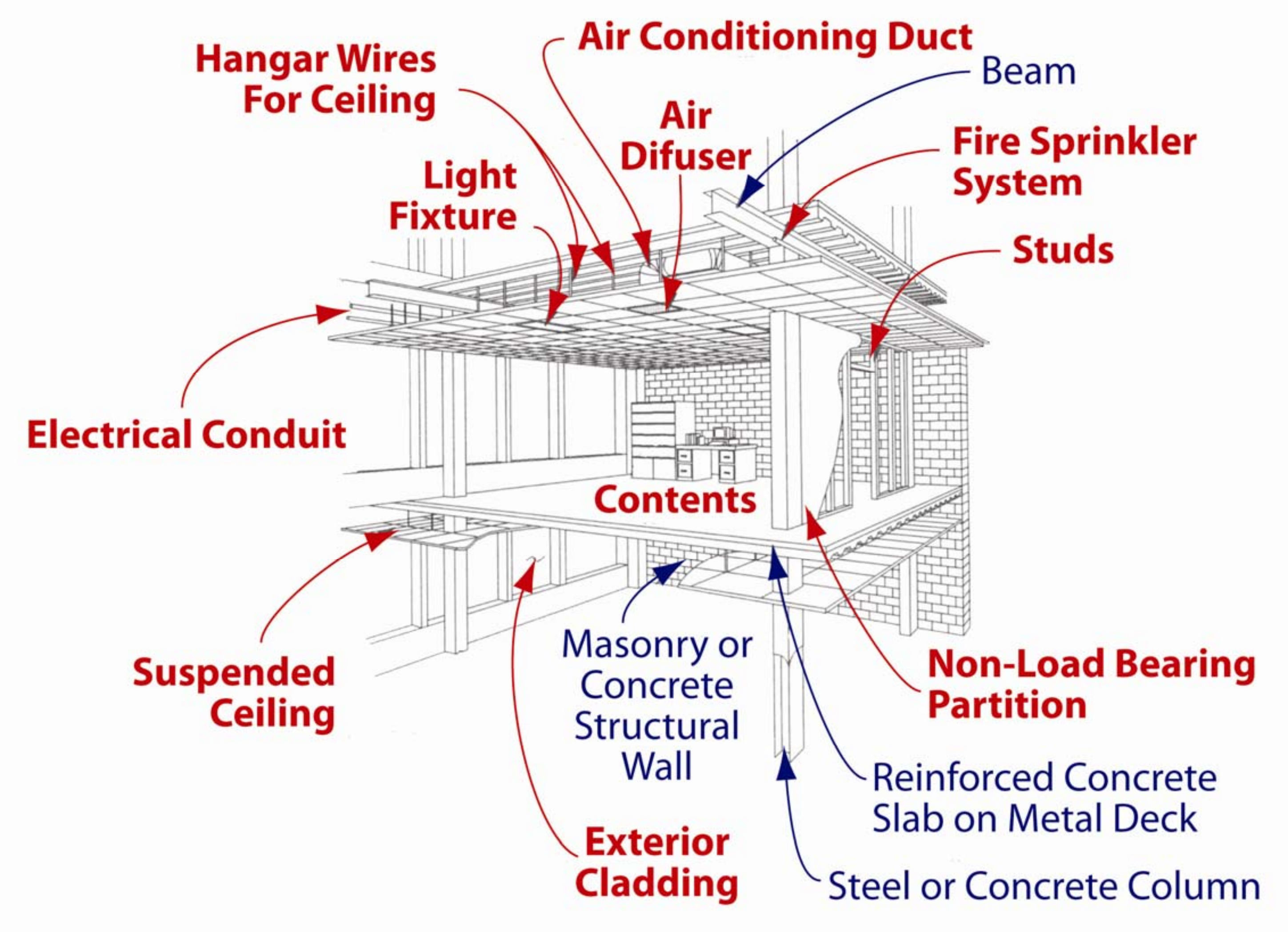
Part 4 – Nonstructural Vulnerability

Building Nonstructural Vulnerability to Earthquakes

RISK = f(HAZARD, VULNERABILITY)

Risk is a function of both the potential hazard (seismic ground motion) and vulnerability (lack of seismic preparedness in structural and nonstructural systems)

Typical Nonstructural Elements



Nonstructural Elements

- Building utilities
- Architectural components
- Medical equipment & medical gases
- Furniture and contents

Building Utilities

- Electrical
- Fire Protection
- Communications
- Mechanical and Plumbing
- Medical Gases

Building Utilities - Electrical

- Emergency generator
  - Batteries
  - Day tank
  - Muffler
  - Fuel system
  - Control equipment

Building Utilities - Electrical

- Motor control cabinets
- Switchgear
- Transformers
- Panelboards
- Conduit
- Cable tray
- Bus duct
- UPS / battery racks

Building Utilities – Fire Protection

- Pumps
- Standpipes
- Distribution piping
- Sprinkler heads
- Valves
- Extinguishers

Building Utilities - Communications

- Telephone switchgear
- Computers
- Batteries
- Radios
- Antennas

Building Utilities – Mechanical & Plumbing

- Boilers
- Chillers
- Air handling units

- Fans
- Water heaters
- Cooling towers

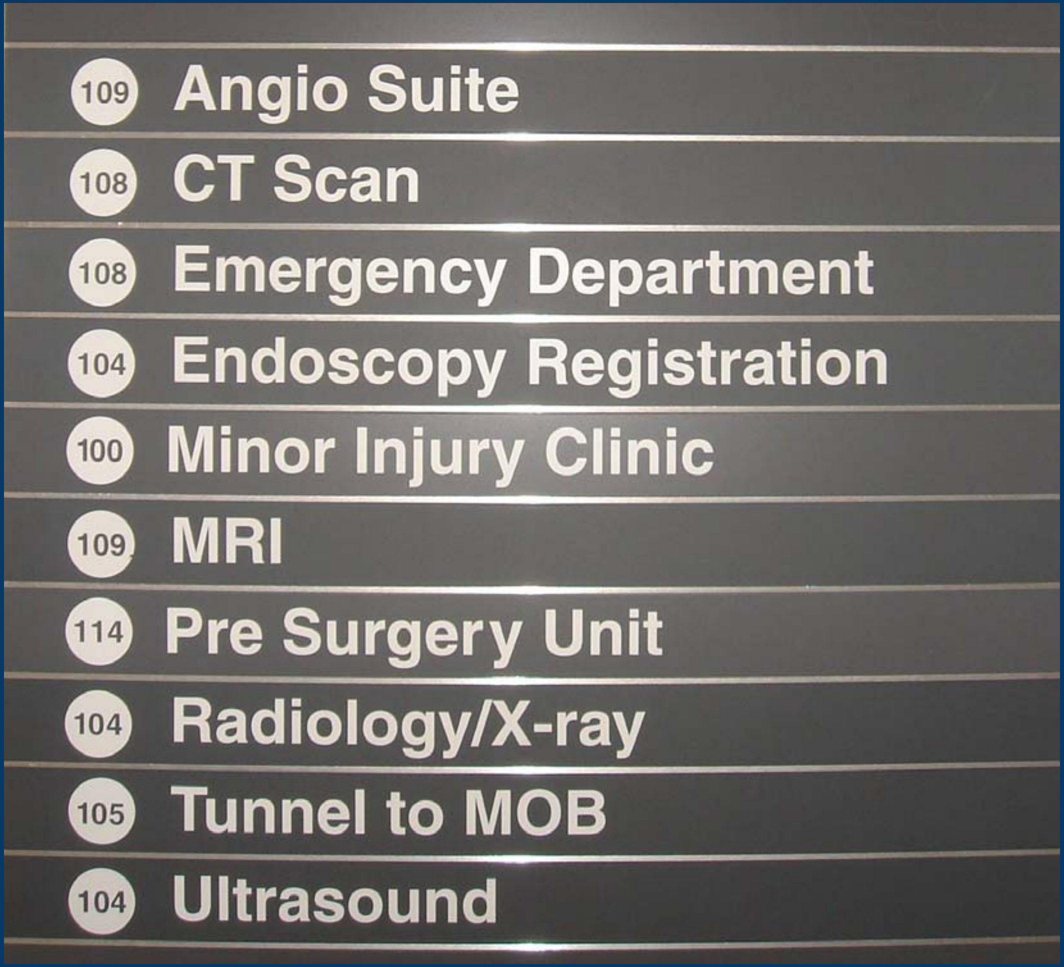
Building Utilities – Mechanical & Plumbing

- Ductwork
- Piping

Architectural Components

- Ceilings
- Partitions
- Lighting
- Cladding
- Parapets
- Access Floors

Medical Equipment



Medical Equipment

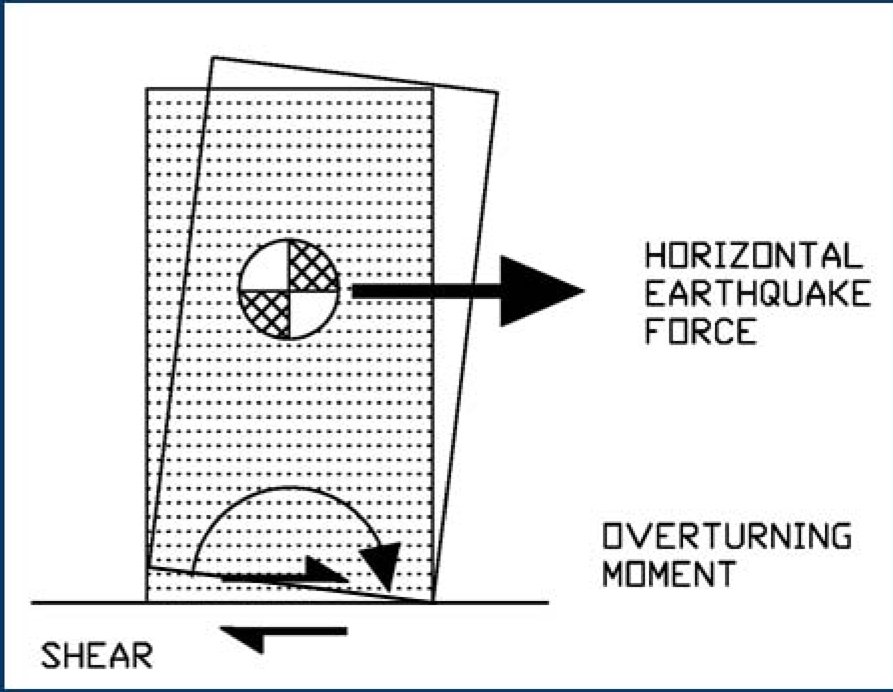
Furniture and Contents

- Computers
- Bookcases
- Storage cabinets
- Televisions
- Monitors
- Carts

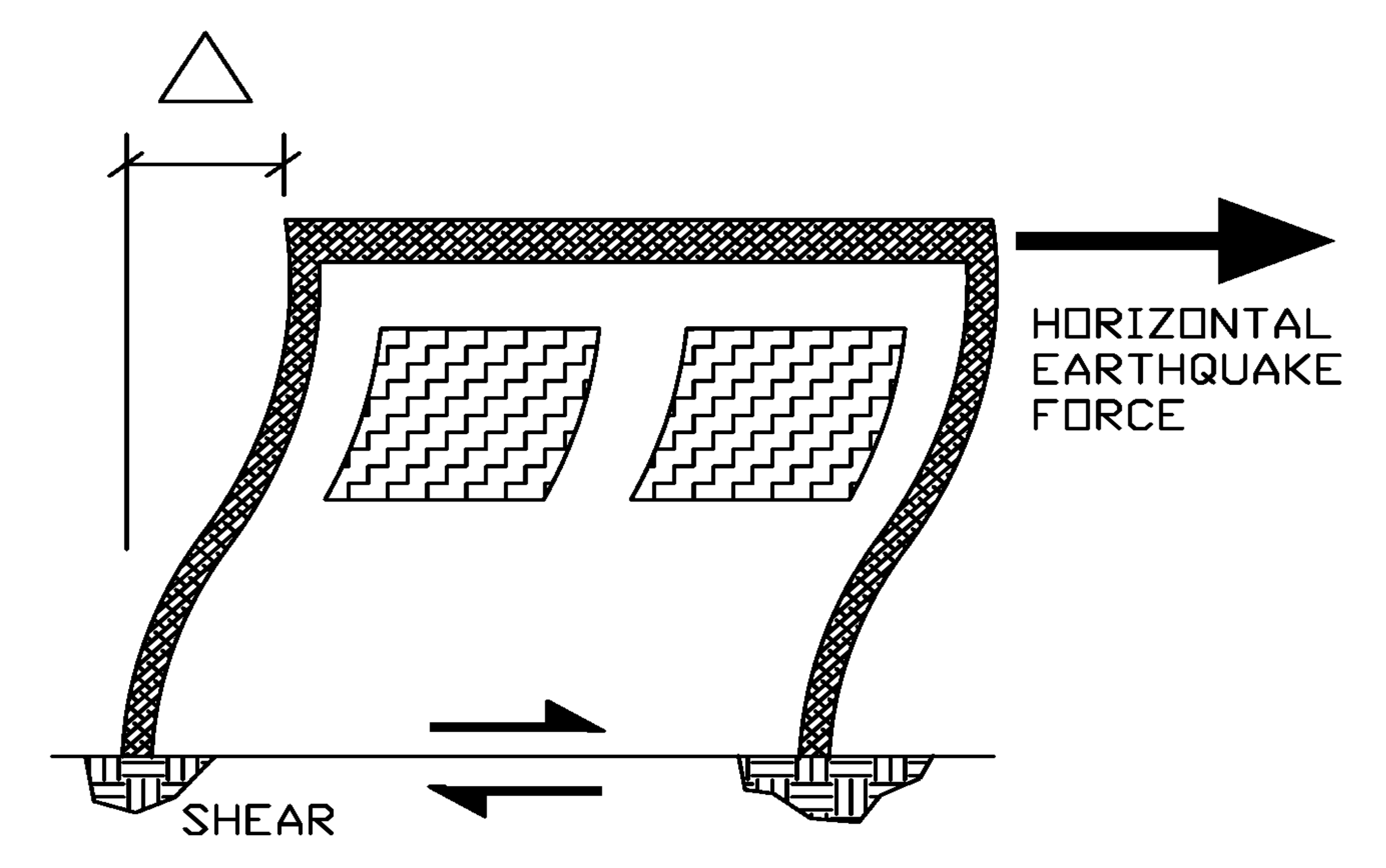
Causes of Nonstructural Damage

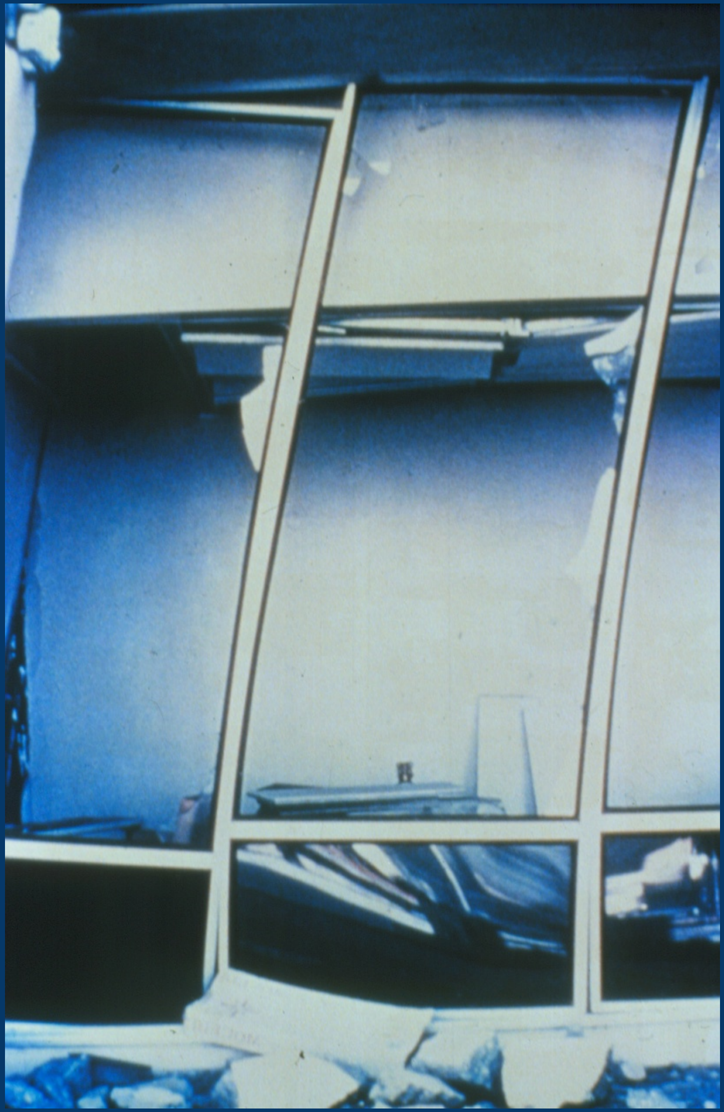
- Shaking – floor acceleration causes items to slide or overturn
- Displacement – building distortions cause damage to connected items

Shaking



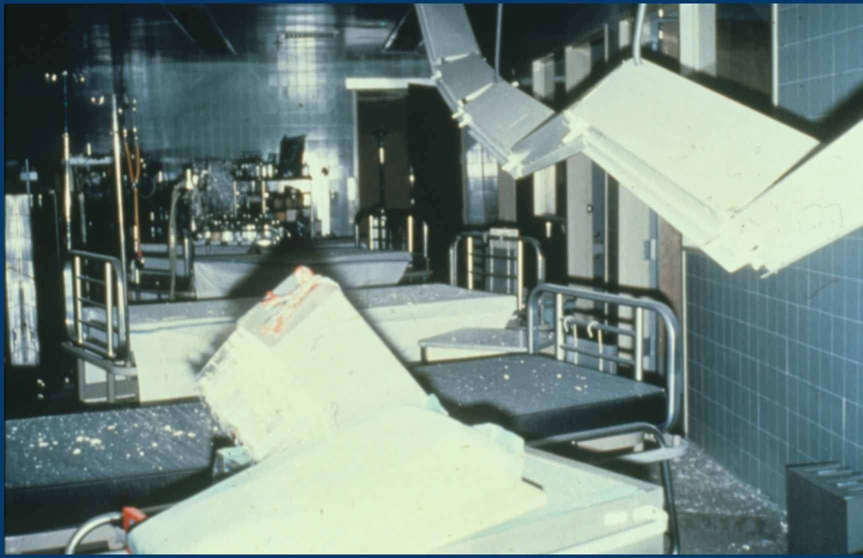
Displacement





Significance of Nonstructural Damage

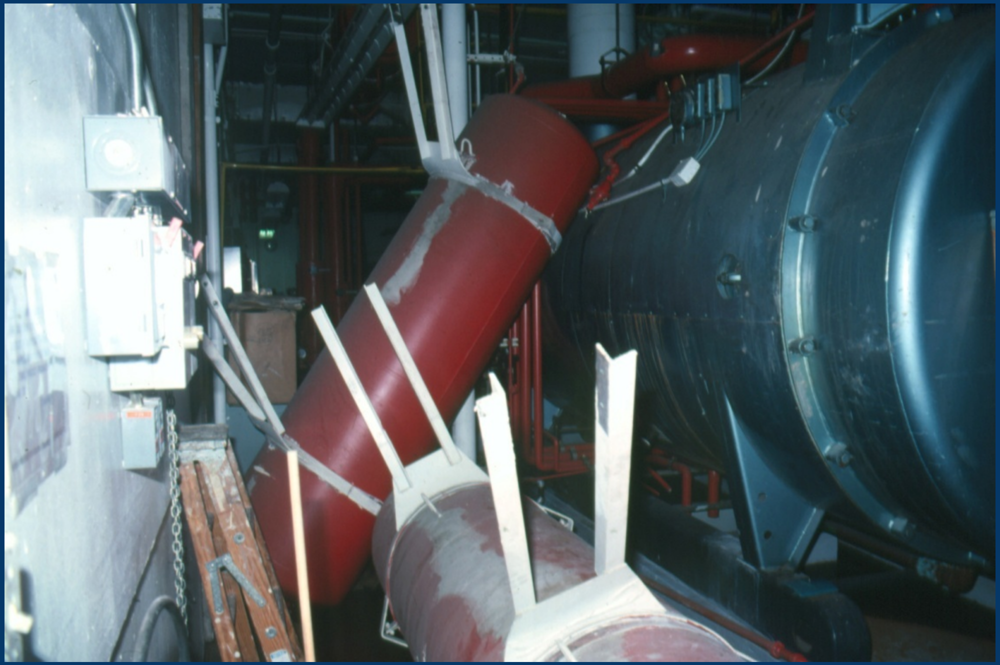
- Damage to nonstructural systems and components typically results in the majority of earthquake economic losses
- Losses can *exceed 50%* of the total value of a facility even though the structure sustains little or no damage



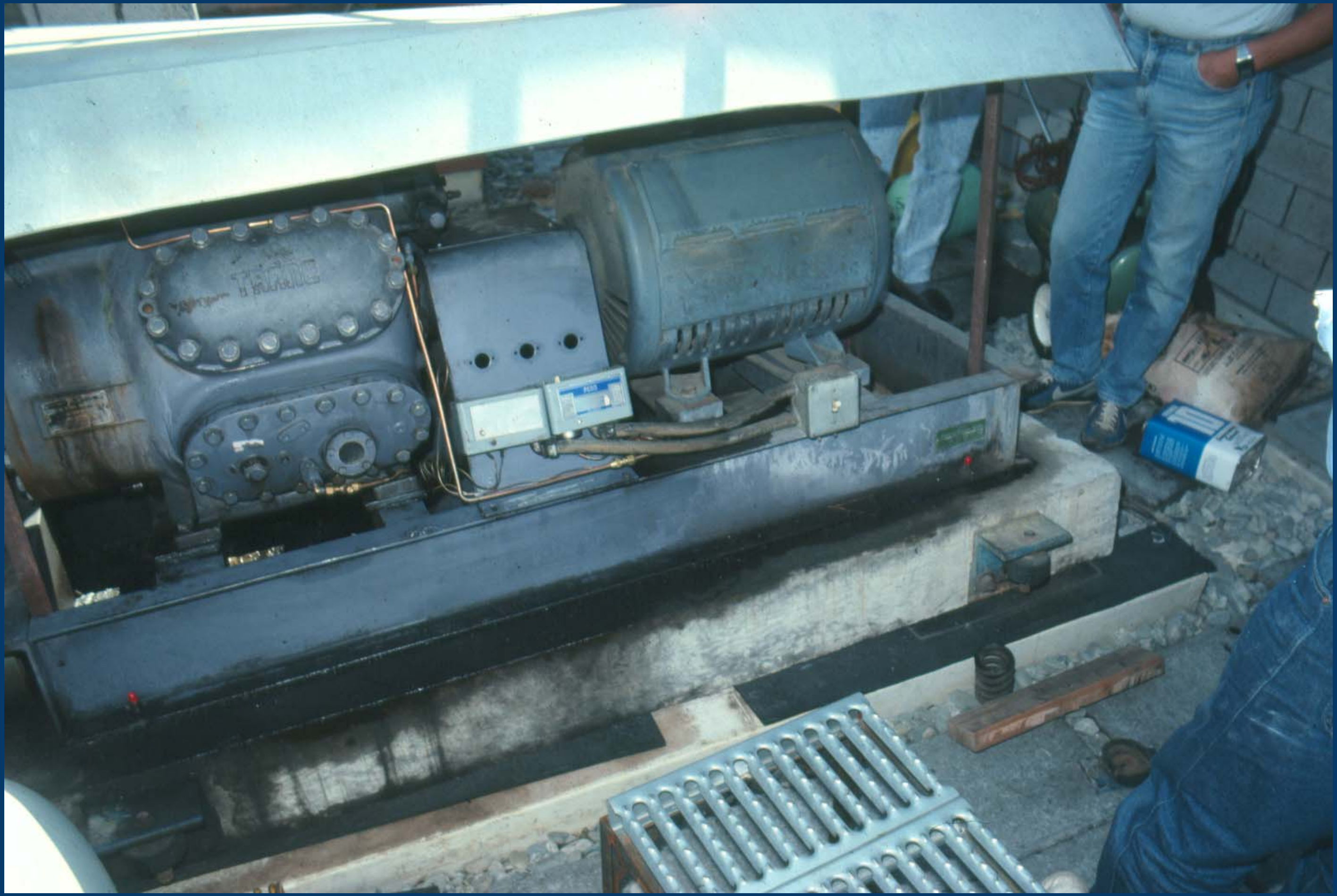
Significance of Nonstructural Damage

- Nonstructural damage impacts:
  - Life Safety
  - Loss of Function
  - Property Damage or Loss
  - Recovery & Restoration Time
  - Business Interruption

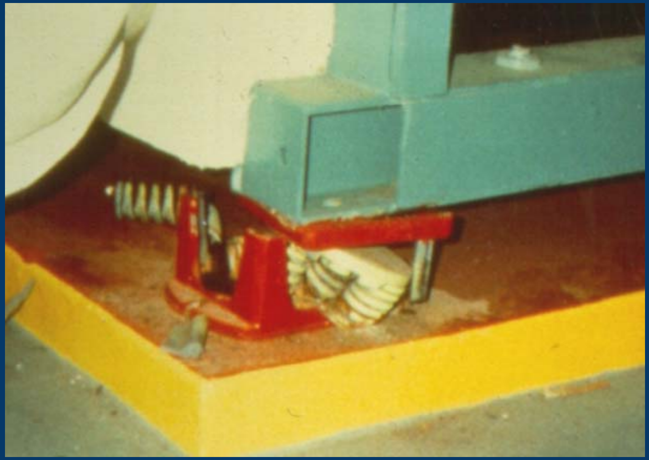
Examples of Damage - Utilities



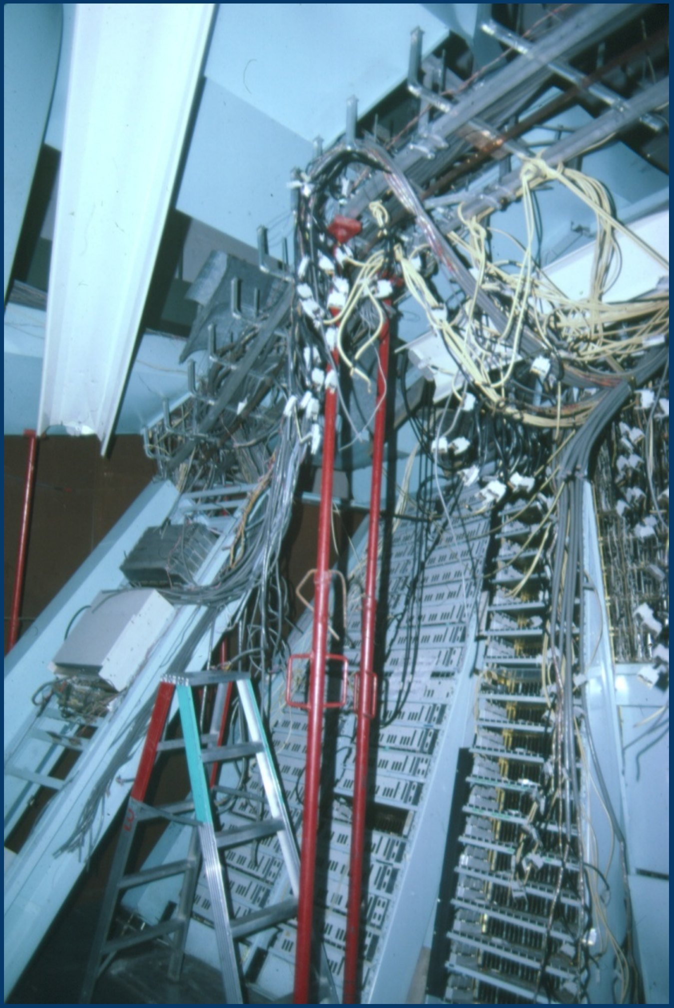
Examples of Damage - Utilities



Examples of Damage - Utilities



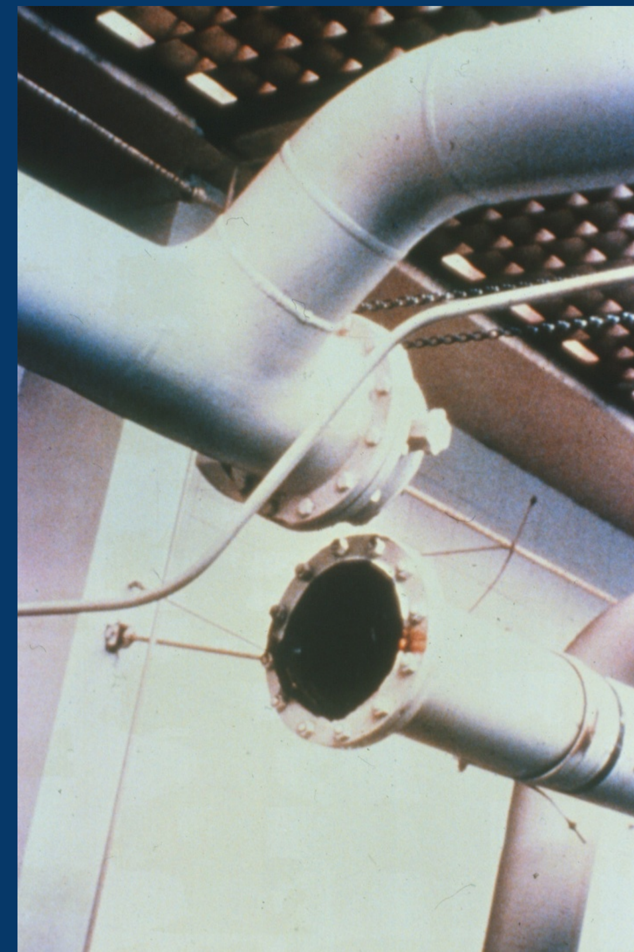
Examples of Damage - Utilities



Examples of Damage - Utilities

Restraints Pulling out from Wall

Examples of Damage - Utilities

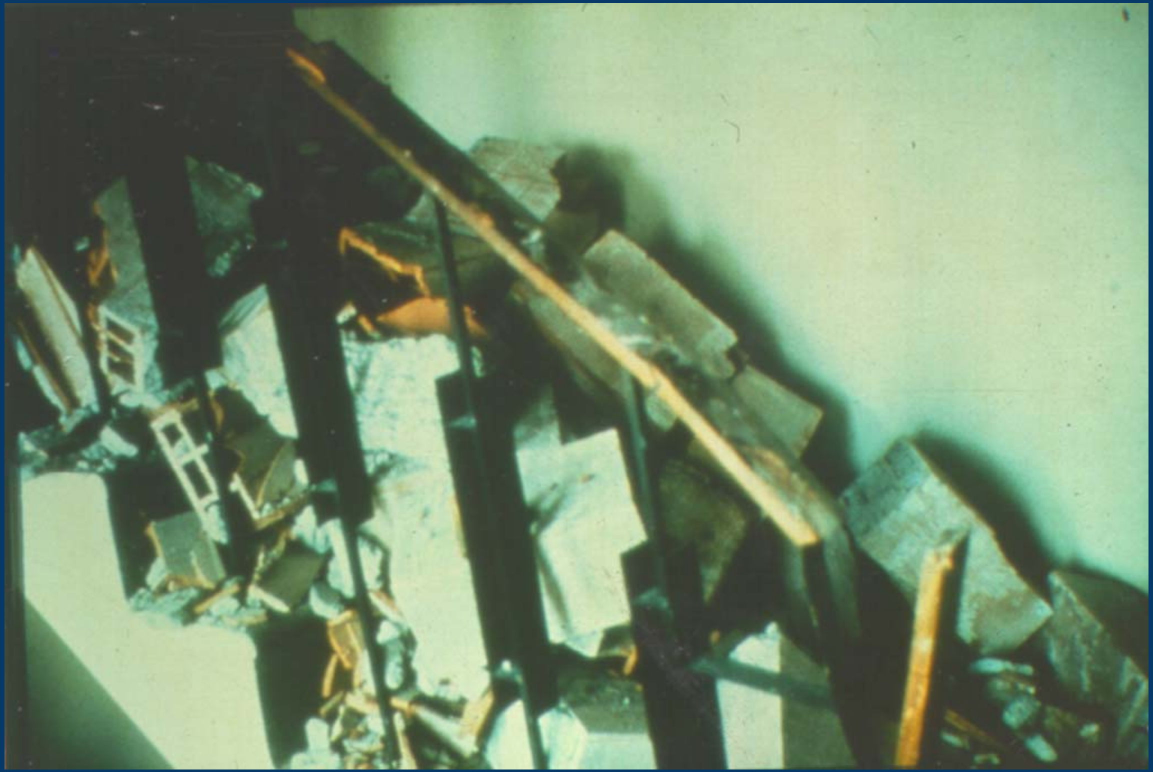


Examples of Damage - Utilities

Examples of Damage – Architectural Elements

Examples of Damage – Architectural Elements

Unreinforced clay-tile/CMU walls at stairs preventing egress



Examples of Damage – Architectural Elements

Examples of Damage – Architectural Elements

Examples of Damage – Contents

Examples of Damage – Contents

Examples of Damage – Contents

Examples of Damage – Contents

The Story of Olive View Hospital

The "New" Olive View Hospital

The "New" Olive View Hospital

Damage from the 1994 Northridge Earthquake

Questions?

Earthquake Mitigation for Hospitals: Workshop

Part 5 – Earthquake Damage Expectations

Earthquake Performance Expectations for the Midwest

Post-Earthquake Expectations for a Major Event Affecting Missouri

Regional Post-Earthquake Expectations

- Historically:
  - MMI Intensities of VII – VIII following an IBC level earthquake event
  - Extensive damage to masonry buildings, old building stock, and nonstructural components & systems
  - Electric Power outages from 1 – 7 days

Regional Post-Earthquake Expectations (Cont.)

- Historically:
  - Natural gas may be shutoff for several days to a few weeks
  - Telephone service will be unreliable for 24 hours, poor service for several days, cellular phones perform better, local exchanges out until power restored
  - Localized water and sewer disruptions from several days to weeks for repairs

Regional Post-Earthquake Expectations (Cont.)

- Historically:
  - Major roadways and bridges generally open, but expect detours and major delays due to inspections

Regional Post-Earthquake Expectations (Cont.)

- Inspection of Buildings for Re-occupancy:
  - Owners calling for building inspections from local building jurisdictions ASAP!
  - Building safety assessments for reoccupation
  - Buildings are tagged (rated) Red, Yellow, or Green
  - Missouri SAVE Coalition trains volunteer inspectors
  - Hospitals should consider hiring an engineering firm to inspect facility

Regional Post-Earthquake Expectations (Cont.)

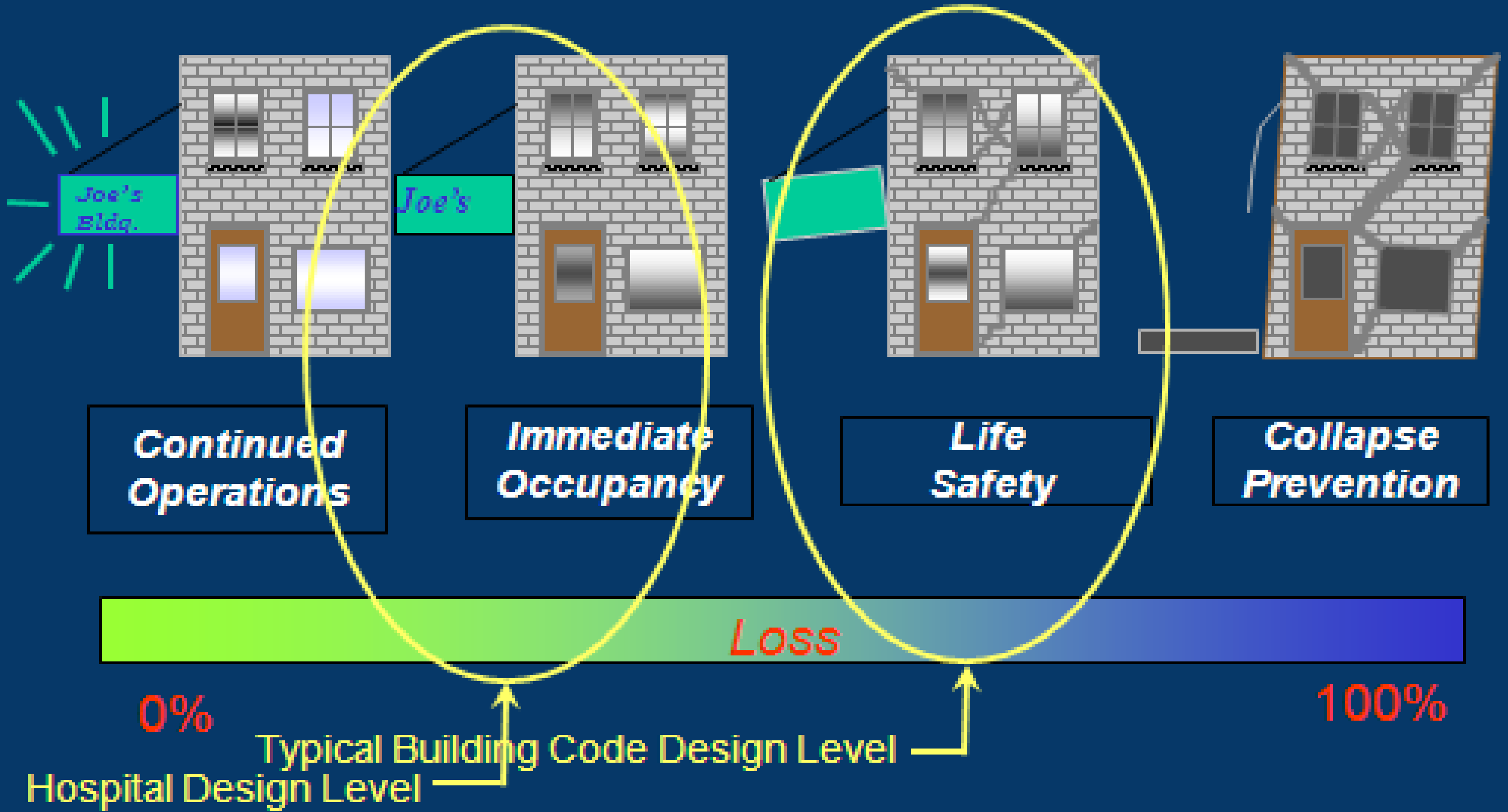
- Potential Consequences:
  - Options for repair/mitigation of life safety hazards will be limited – mitigation may likely be mandated
  - Reactionary public and political demands
  - Area contracting and repair companies stretched to the limit
  - Financial considerations for clean-up, repair, and mitigation
  - Chaotic environment

Why does so much Damage Occur?

- Building Code Design Philosophy
- Seismic Design Process for Nonstructural Components
- Construction Process
- Quality of Construction
- Increased Cost for Enhanced Seismic Anchorage Impedes Implementation

What the building code says!

Model Building Code Earthquake Performance



Model Building Code Design Philosophy

- Model Building Codes for typical buildings (BOCA, SBC, UBC, IBC):
  - Provide a *Minimum* set of design requirements for the protection of public safety, health, and general welfare. A LIFE SAFETY code
  - Do not protect against PROPERTY DAMAGE or LOSSES
  - International Building Code (IBC) should be more effective
- Hospitals are required to have a higher level of design over typical buildings

Model Building Code Design Philosophy (Cont.)

- Acceptable building performance under the Model Building Codes (UBC, BOCA, SBC, & IBC) for Life Safety means:
  - Significant structural damage
  - Extensive nonstructural damage
  - Building may not be safe to reoccupy until repaired
  - Building function may be severely impacted

Model Building Code Nonstructural Design Requirements

- Design Philosophy:
  - Predominantly life safety performance
    - Cladding and wall systems
    - MEP equipment & systems carrying flammable, combustible or highly toxic contents
    - HVAC ductwork transporting hazardous materials
    - Emergency or standby power systems – life safety systems
  - Is not intended to protect against property damage
- ***Minimum*** set of design requirements

Nonstructural Components - Earthquake Design Process

- Who is the most knowledgeable and responsible party to perform the seismic design for Nonstructural Components?
  - Structural/seismic engineer
  - Architect
  - Electrical engineer
  - Mechanical engineer
  - IT/Communications engineer
  - Fire Protection engineer
  - Construction contractors

Earthquake Design Process

- Dependent upon the delivery system used:

OWNER/ DEVELOPER — ARCHITECT

Program Manager

<u>DESIGN TEAM</u>

Civil	Structural
Architectural	MEP Systems
Fire Protection	Communications
IT Systems	

Earthquake Design Process (Cont.)

- Subject to the individual Project Architect
- Varies project to project
- Local jurisdiction dependent and enforcement
- Typically addressed by the individual MEP or Architectural discipline
- Seismic Performance Requirements written into the MEP design specifications for Contractor implementation.
- This typical process:

ABDICATES RESPONSIBILITY FOR THE SEISMIC DESIGN OF ARCH/MEP COMPONENTS TO THE RESPECTIVE DISCIPLINE CONSTRUCTION CONTRACTORS

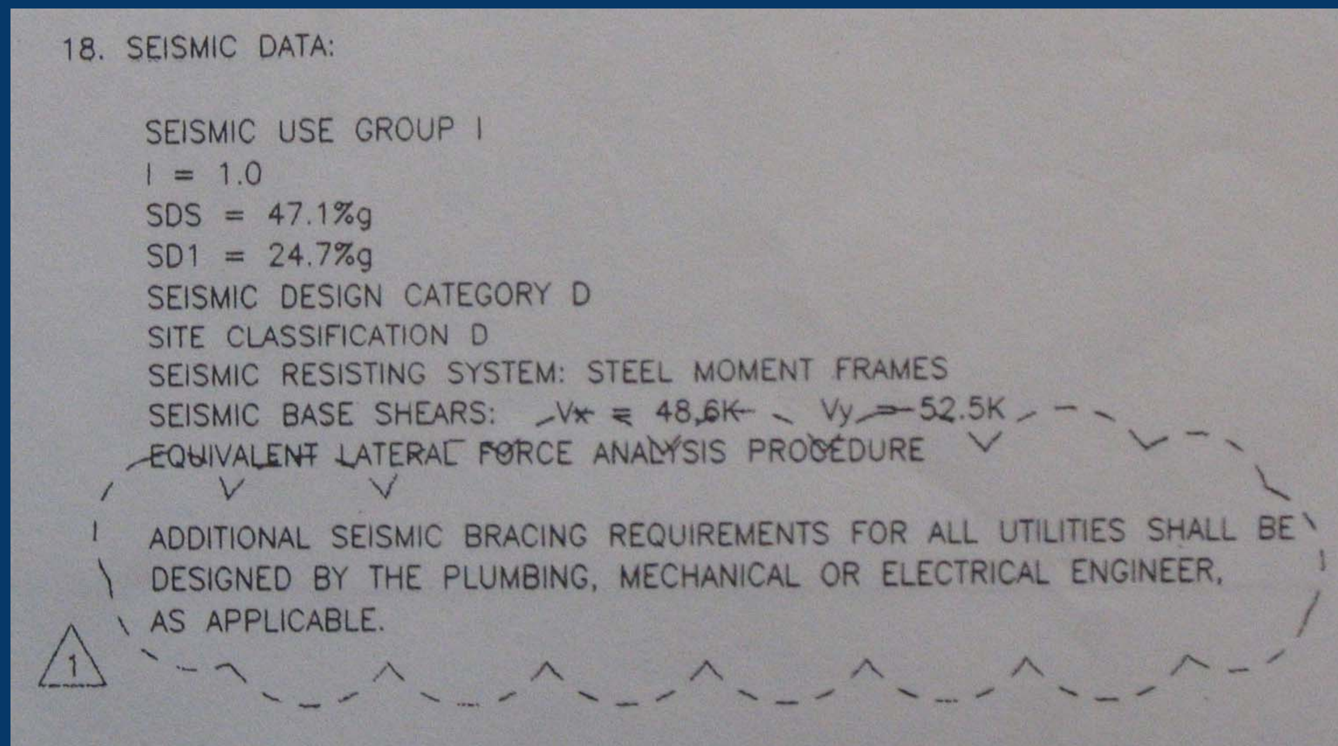
Earthquake Design Process (Cont.)

- Structural/Seismic design requirements:
  - *International Building Code*
  - *ASCE 7-05*
- MEP design requirements:
  - *International Mechanical Code*
  - *International Electrical Code*
  - *International Plumbing Code*
  - *International Fire Code*

$$\begin{cases} F_p = \dfrac{0.4 a_p S_{DS} W_p}{\left[\dfrac{R_p}{I_p}\right]}\left[1 + 2\dfrac{z}{h}\right] \\ D_p = \delta_{xA} - \delta_{yA} \end{cases}$$

Earthquake Design Process (Cont.)

- Structural approach to NS Component design?


18. SEISMIC DATA:

SEISMIC USE GROUP I
I = 1.0
SDS = 47.1%g
SD1 = 24.7%g
SEISMIC DESIGN CATEGORY D
SITE CLASSIFICATION D
SEISMIC RESISTING SYSTEM: STEEL MOMENT FRAMES
SEISMIC BASE SHEARS: Vx = 48.6K Vy = 52.5K
EQUIVALENT LATERAL FORCE ANALYSIS PROCEDURE

ADDITIONAL SEISMIC BRACING REQUIREMENTS FOR ALL UTILITIES SHALL BE DESIGNED BY THE PLUMBING, MECHANICAL OR ELECTRICAL ENGINEER, AS APPLICABLE.

1

Earthquake Design Process (Cont.)

- Example – Electrical equipment seismic design:
  - Specification Section 16010 – *General Electrical Provisions with Seismic Design Requirements*
  - Individual Spec. Sections provide electrical performance requirements only
    - Section 16110 - Raceways
    - Section 16425 – Switchboards
    - Section 16460 – Dry Type Transformers
    - Section 16470 – Panelboards
    - Section 16481 – Motor Control Centers

Construction Process

GENERAL CONTRACTOR

Subcontractors

Building Structure →
- Steel Erector
- Concrete Work

Constructs the Seismic Design
(on design drawings)

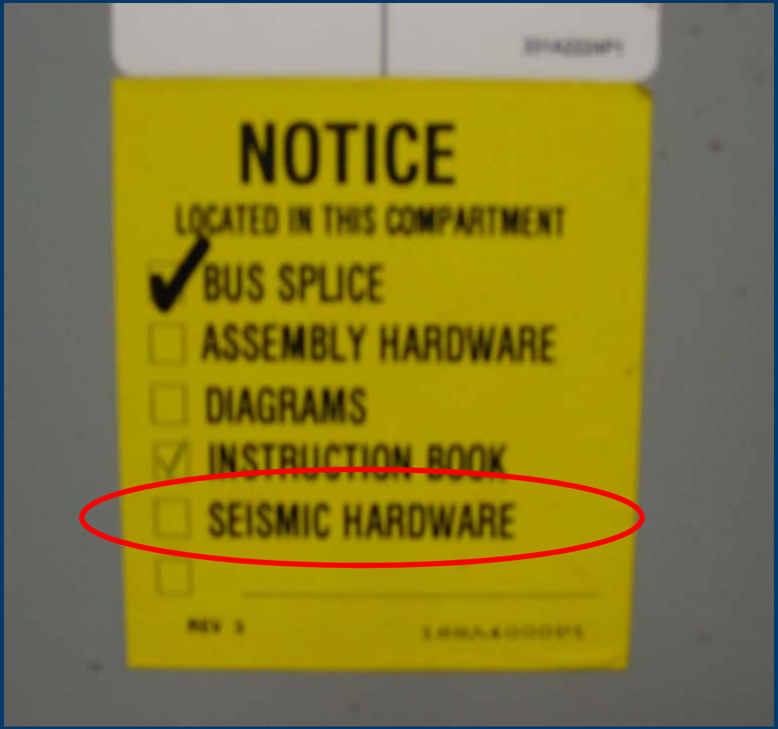
Nonstructural Components →
- Architectural
- Mechanical
- Electrical
- Fire Protection
- IT Systems
- Etc.

Seismic Design?
(Must Implement thru Performance Specs)

Construction Process (Cont.)

- Electrical equipment seismic design:
  - General Contractor (GC)
    - Electrical Contractor (EC)

- Example – Switchboards
  - EC Orders Equipment
  - Provides Equipment Supplier with Spec. Section 16425
  - Section 16010 – General Provisions with seismic design requirements are not provided to the Equipment Supplier



Construction Process (Cont.)

Construction Issues for MEP Systems:

- Contractor designed
- Trade sequencing
- Field routed
  - Conduit
  - Piping
  - Cable-tray
  - Ducting

Earthquake Performance Expectations?

Earthquake Performance Expectations?

Natural Gas Line

Quality of Construction

- Why is Proper Construction Important?
  - Assures the expected earthquake performance objectives
  - Assures reduction in risk or damage to the component itself
  - Assures a reduction in risk or damage to adjacent or closely located items – falling, overturning, swinging or impacting
  - Assures reduction in life safety risk to building occupants
  - Assures for critical facilities the needed operability assurances necessary for Immediate Occupancy (e.g., hospitals, fire stations, police stations, other critical facilities, etc.)

Improper construction is more prevalent than you think!

Structural Issues can Happen!

Adequate Anchorage?

Incorrect Routing – Fire Protection Piping

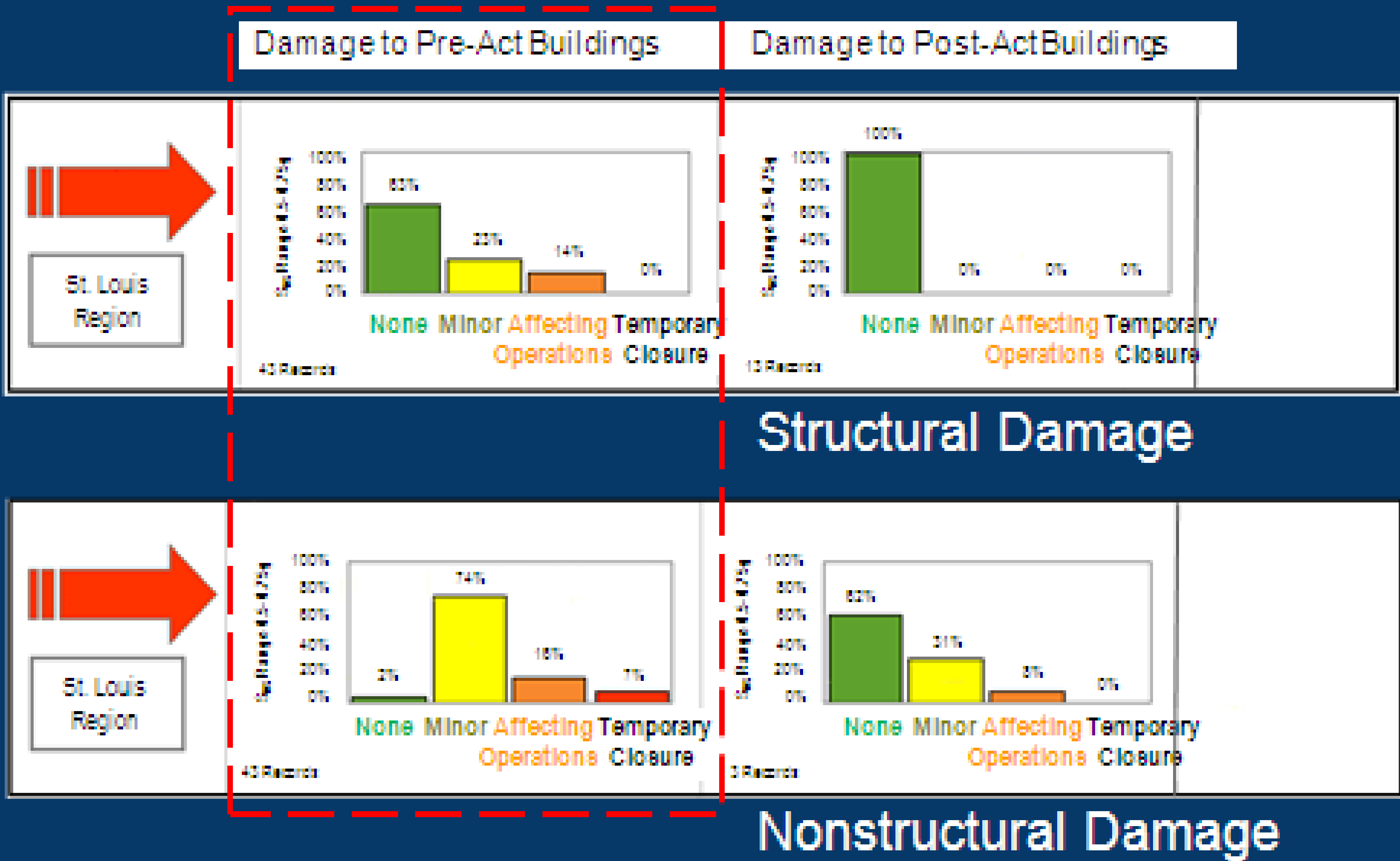
Communication Cable Support?

Emergency Generator Adequate?

Expectations for Hospitals

- Study by Holmes & Burkett, EERI 8th NCEE – California Hospital Earthquake Performance
- Primary purpose - identify levels of ground motion affecting operational performance of hospitals
- 218 Hospitals or data points that experienced earthquake ground shaking
- Pre-1973 Hospitals considered representative of hospitals outside of California to assess performance

Expectations for Hospitals (Cont.)

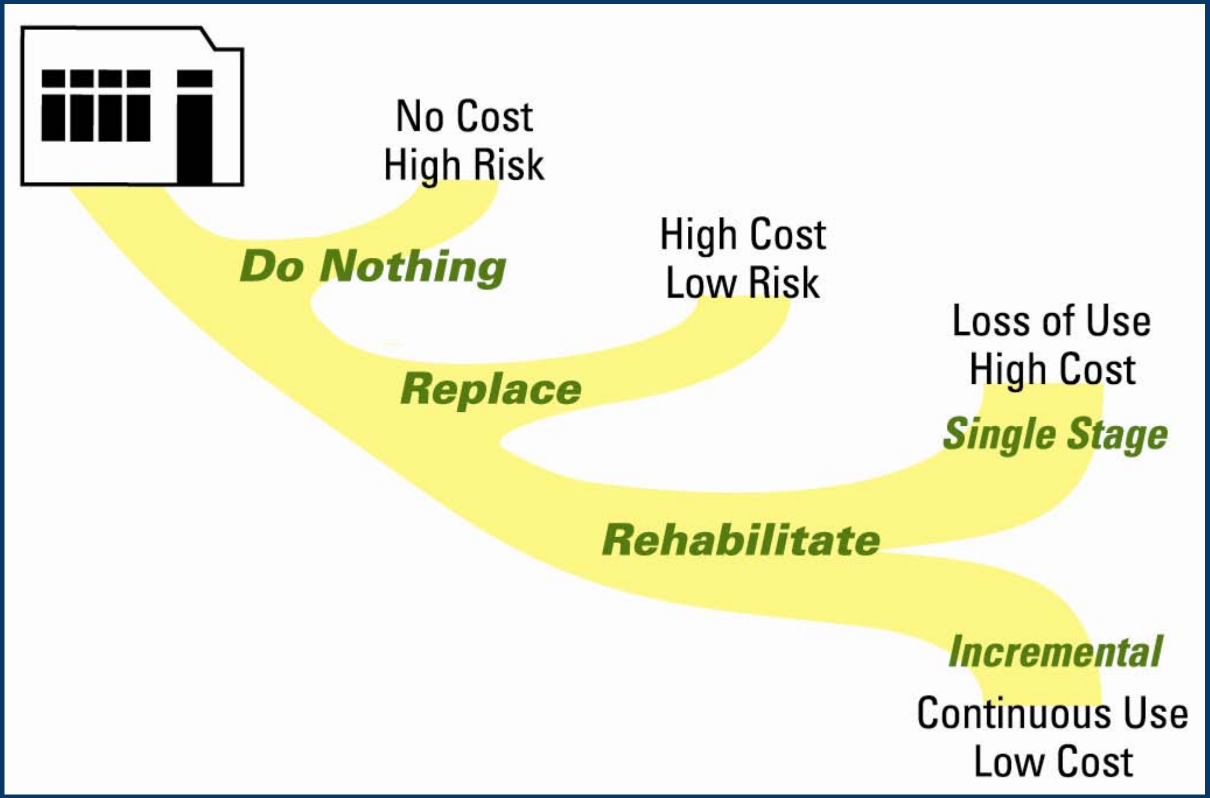


Questions?

Earthquake Mitigation for Hospitals: Workshop

Part 6 – Risk Reduction Overview

Overview of Seismic Risk Reduction



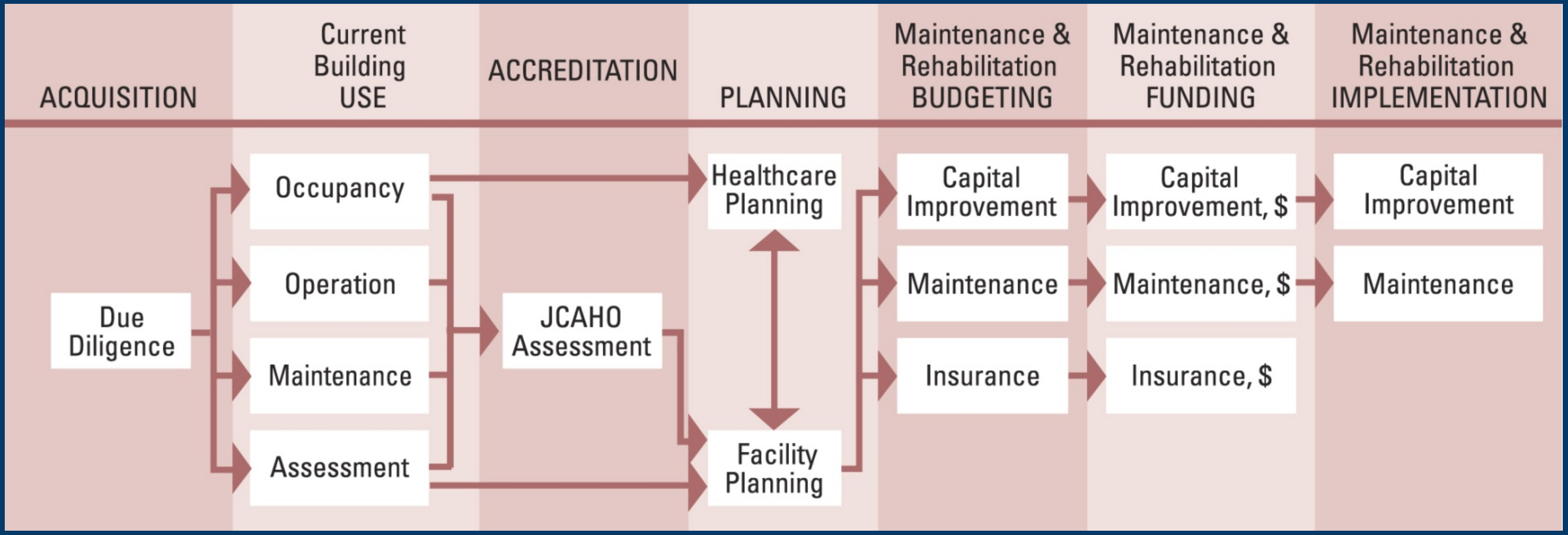
Earthquake Mitigation for Hospitals: Workshop

Part 7 - Planning and Managing the Process

Planning and Managing the Process of Seismic Risk Reduction

- Planning for earthquake risk reduction requires a coordinated and integrated effort by facility managers, risk managers, and financial managers.

Planning and Managing the Process of Seismic Risk Reduction



AQUISITION → Current Building USE → ACCREDITATION → PLANNING → Maintenance & Rehabilitation BUDGETING → Maintenance & Rehabilitation FUNDING → Maintenance & Rehabilitation IMPLEMENTATION

Acquisition

Hospital buildings and their professional staffs are often acquired as part of a single transaction. The **due diligence** process that precedes an acquisition is intended to identify and quantify all the liabilities or potential liabilities related to the asset being acquired.

AQUISITION → Current Building USE → ACCREDITATION → PLANNING → Maintenance & Rehabilitation BUDGETING → Maintenance & Rehabilitation FUNDING → Maintenance & Rehabilitation IMPLEMENTATION

Use

The use phase of facility management includes:

- Occupancy: healthcare delivery and support
- Operation: facility support
- Maintenance: enable Occupancy and Operation to continue over time
- Assessment: facility survey and inspection

Accreditation

The accreditation phase of facility management consists of a variety of evaluation and inspection activities.

Planning

The planning phase consists of projecting and forecasting future needs in two separated but related areas:

- Healthcare planning
- Facility planning

AQUISITION › Current Building USE › ACCREDITATION › PLANNING › Maintenance & Rehabilitation BUDGETING › Maintenance & Rehabilitation FUNDING › Maintenance & Rehabilitation IMPLEMENTATION

Budgeting

The budgeting phase consists of the projection of future financial resources required to meet future needs in three areas relevant to facility management:

- Capital
- Maintenance
- Insurance

Funding

The funding phase consists of obtaining the financial resources to meet hospital needs. The funding of hospital capital, maintenance, and insurance budgets can come from various sources:

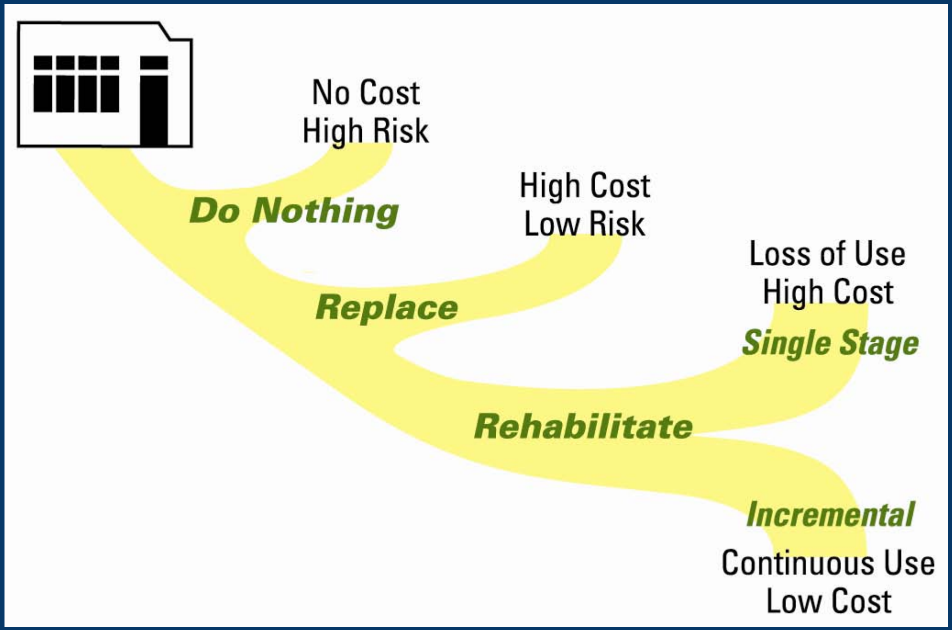
- Revenue
- Bonds
- Grants
- Interest income
- Taxation

Implementation

The implementation phase includes design and construction in four categories of projects:

- New building construction
- Building acquisition
- Capital improvement
- Maintenance

Overview of Seismic Risk Reduction

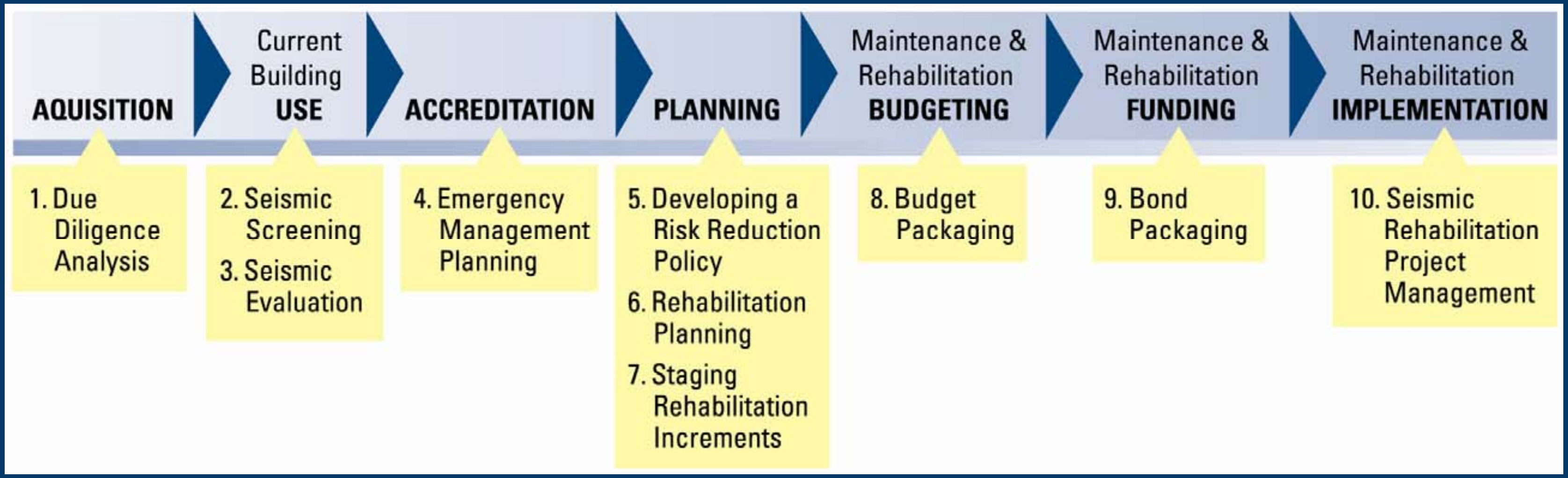


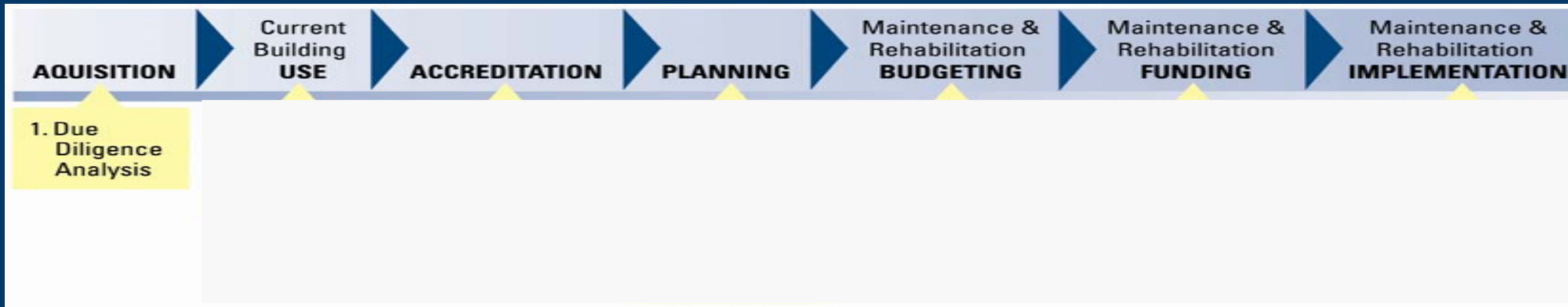
Planning and Managing the Process of Seismic Risk Reduction

- 10 specific activities can be added to the facility management process to implement an incremental seismic rehabilitation program.
- 9 additional activities can be added to further reduce seismic risk.
- There are two ways to start reducing seismic risk. *EQ drills, contents mitigation*

Elements of an Incremental Seismic Rehabilitation Program

Elements of an Incremental Seismic Rehabilitation Program



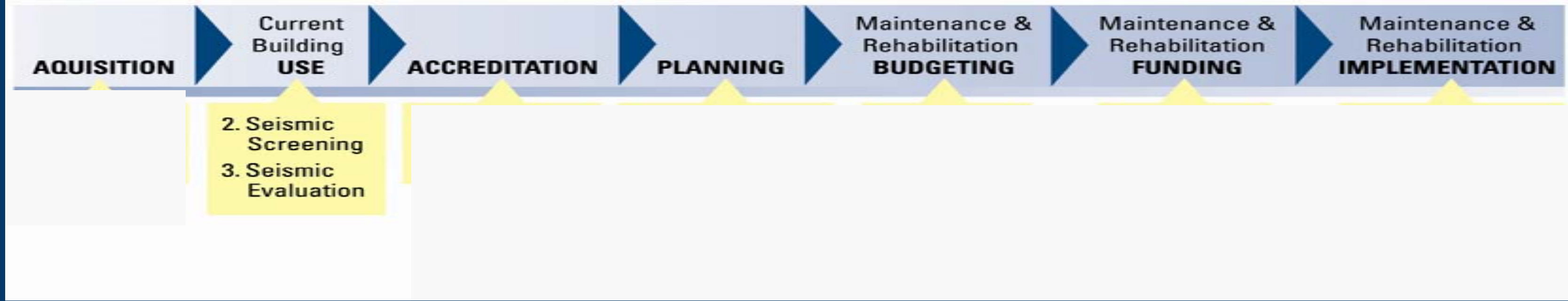


1. Due Diligence Analysis

Due diligence should include a probabilistic analysis of potential earthquake risks:

- Building stability
- Site stability
- Building damageability
- Building content damageability
- Business interruption

Resource: ASTM E 2026

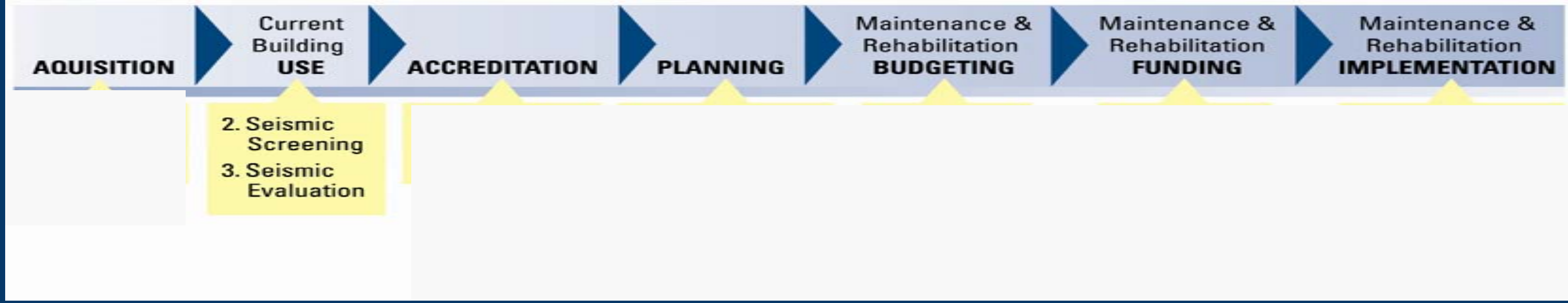


2. Seismic Screening

Seismic screening of a healthcare organization's building inventory can be incorporated into other building assessment activities:

- Determine building structure type
- Relative vulnerability score of each building

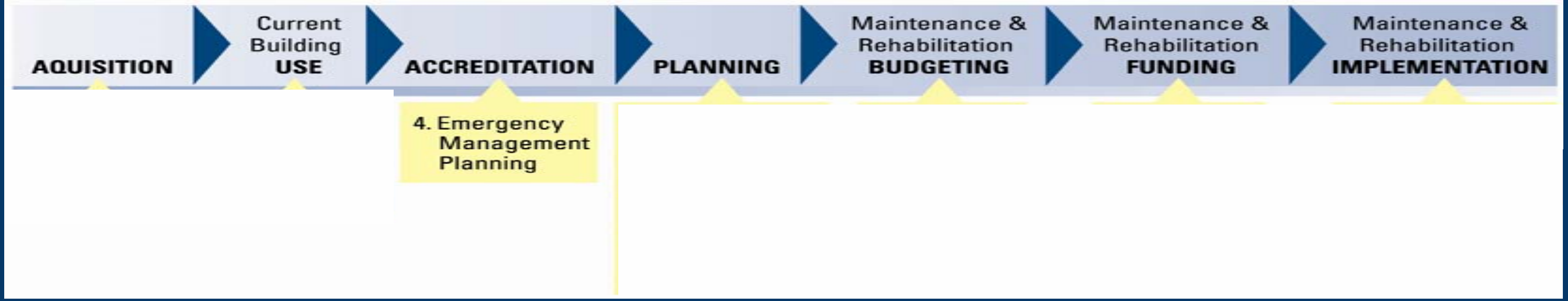
Resource: FEMA 154



3. Seismic Evaluation

Seismic evaluation is an engineering analysis of individual healthcare buildings that have been screened as relatively more vulnerable.

Resource: ASCE 31 (based on FEMA 310)



4. Emergency Management Planning

Emergency management planning is required by JCAHO Environment of Care standards. Seismic screening and evaluation can support and enhance demonstration of compliance with JCAHO standards EC.1.4 and EC.2.4

Resource: ASHE, *Hazard Vulnerability Analysis*

5. Developing a Risk Reduction Policy

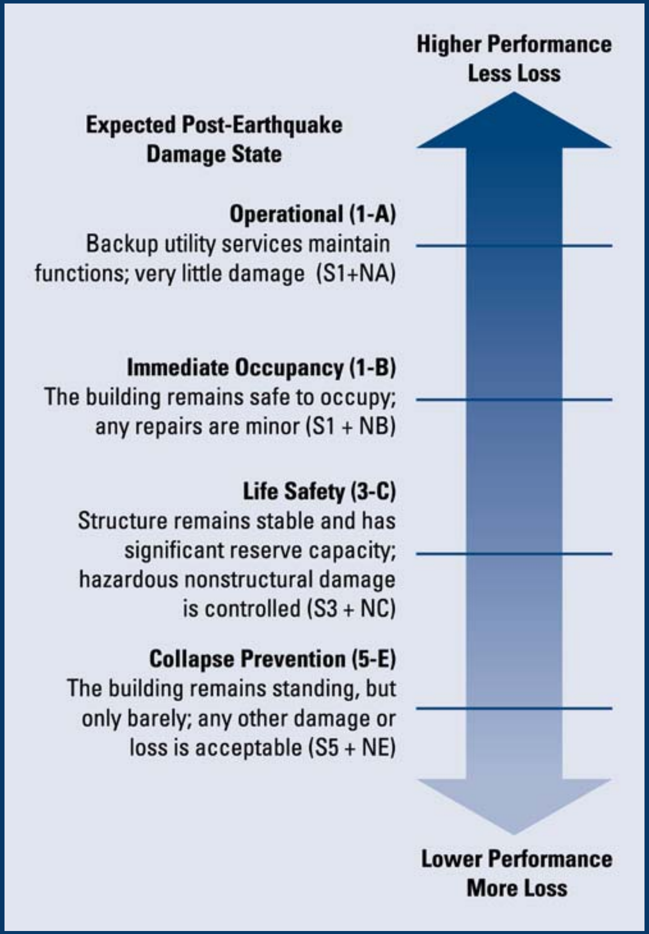
- The Board of Directors should adopt a policy statement supporting seismic risk reduction.
- Such a policy should, at a minimum, establish seismic performance objectives for the healthcare organization's various buildings.

6. Seismic Rehabilitation Planning

- Establish seismic target performance levels
- Prioritize rehabilitation opportunities (“worst first”)
- Define rehabilitation increments
- Integrate with other planned rehabilitation work

Resource: ASCE 41 (based on FEMA 356)

Target Performance Levels



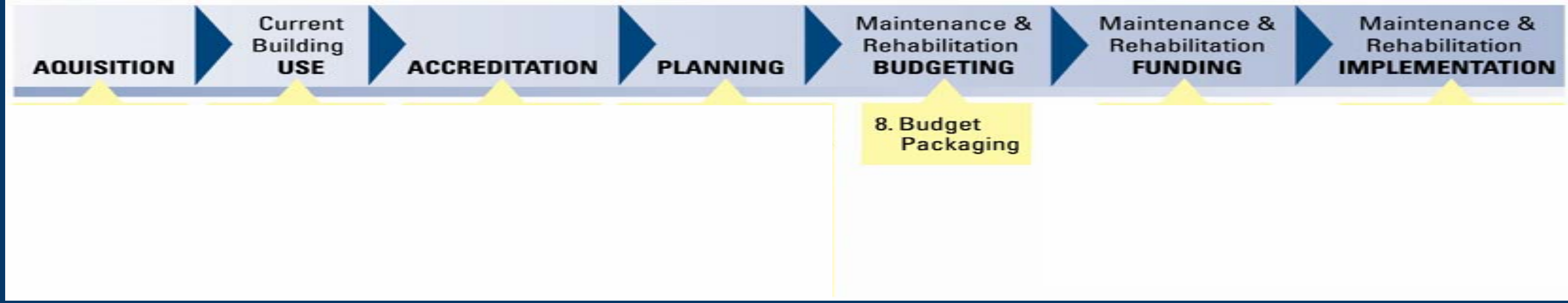
Target Performance Levels

	Target Building Performance Levels — Lower Performance, More Loss → Higher Performance, Less Loss			
	Collapse Pervention Level (5-E)	Life Safety Level (3-C)	Immediate Occupancy Level (1-B)	Operational Level (1-A)
Overall Damage	Severe	Moderate	Light	Very Light
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operations are functional.
Nonstructural Components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged	Equipment and contents are generally secure, but may not be operable due to mechanical failure or lack of utilities.	Negligble damage occurs. Power and other utilities are available, possibly from standby sources.
Comparison with performance intended for buildings designed under the *NEHRP Provisions* for the Design Earthquake	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Less damage and lower risk.	Much less damage and lower risk.

7. Staging Seismic Rehabilitation Increments

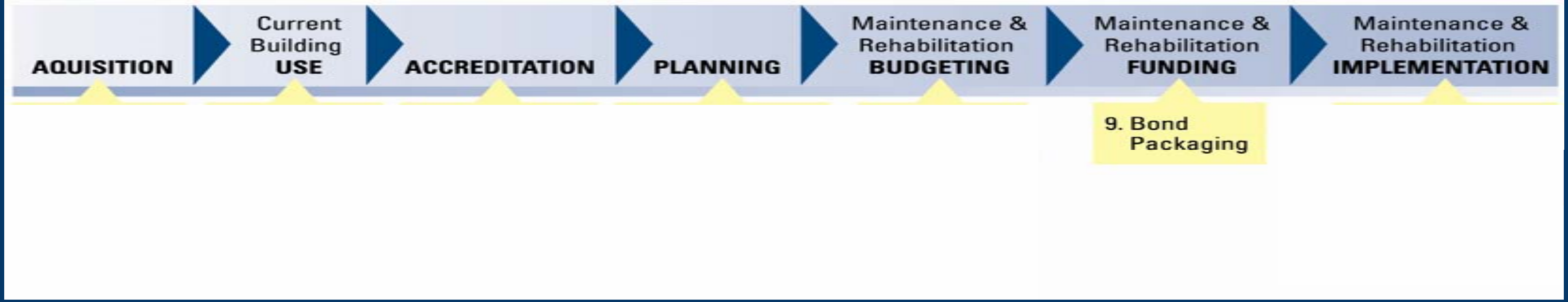
Incremental seismic rehabilitation affords great flexibility in the sequence and timing of actions:

- Get started as soon as possible
- Even if completion takes 10-20 years, most of the risk reduction benefit is realized
- There is a wide margin of options and it is possible to increase the vulnerability for a limited period.



8. Budget Packaging

- Carefully plan how to present the incremental seismic rehabilitation budgets, given political and financial realities and Medicare’s depreciation schedules
- It is unlikely that healthcare organizations outside California can raise funds for a seismic rehab program for all their buildings
- It may be necessary to package seismic rehabilitation with other work to get it funded



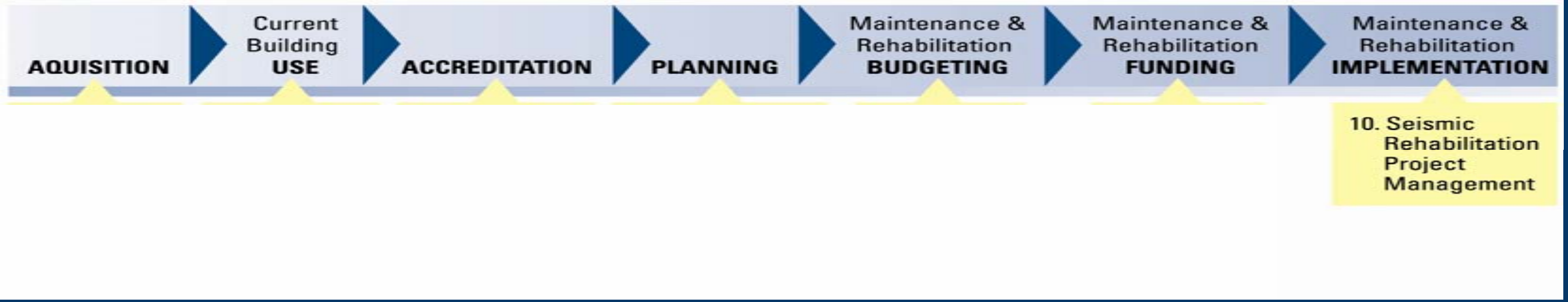
9. Bond Packaging

Bond financing is one of five financing mechanisms for seismic rehabilitation. It is important to ensure that bond-financed incremental seismic rehabilitation does not include categories of work precluded by law or regulation.

Bond Financing

Experience with bond-financed incremental seismic rehabilitation has been limited to school districts. Most extensive is that of Seattle Public Schools. Seattle's experience may be of interest to some healthcare organizations. Two types of bonds were used, based on state law:

- Capital Levy Bonds (smaller projects)
- Capital Improvement Bonds (larger projects)

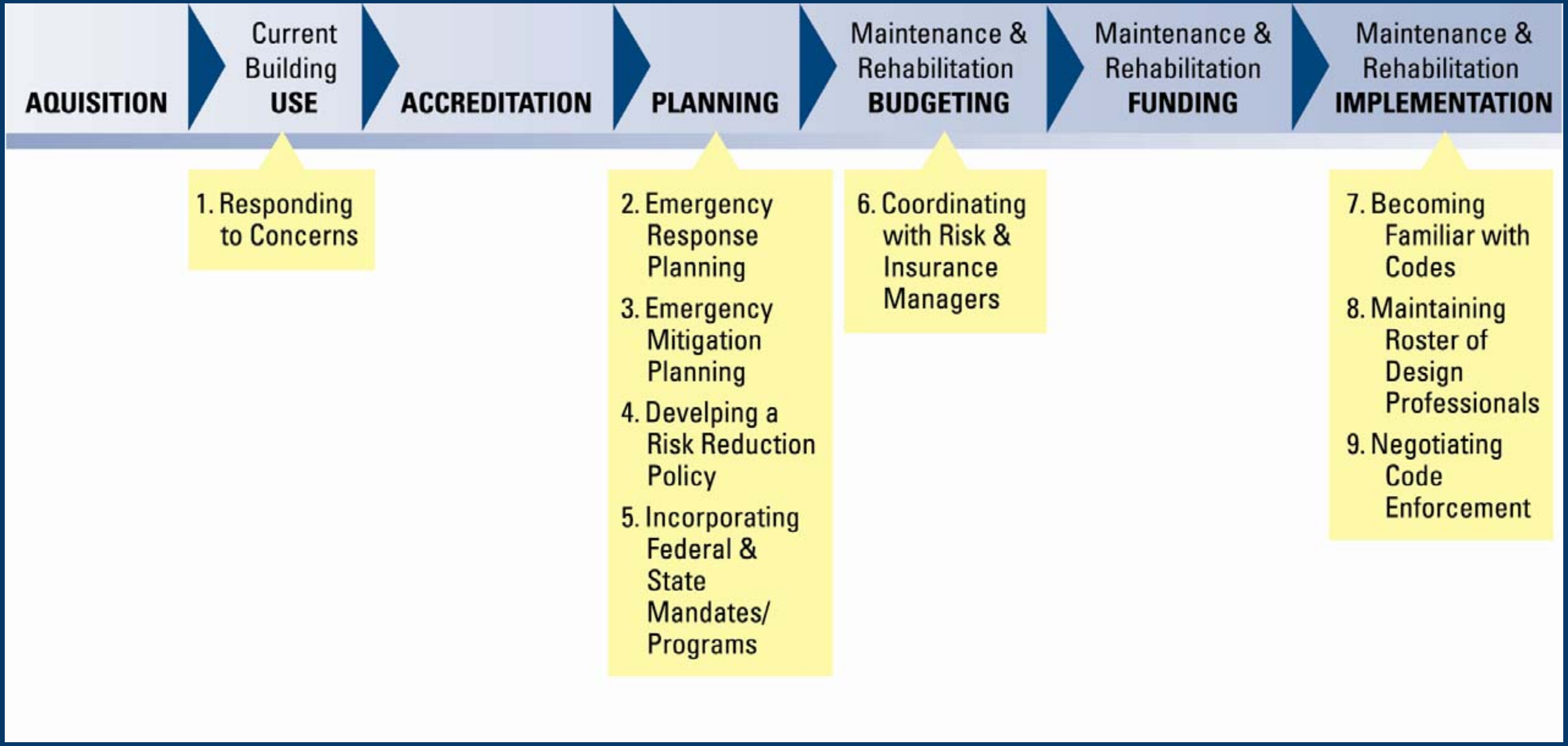


10. Seismic Rehabilitation Project Management

For incremental seismic rehabilitation:

- Brief or train design professionals preparing the bid documents on the rationale behind the rehabilitation measures
- Continuity of Operations
- Ensure continuity of documentation
- Conduct a pre-bid conference

Additional Opportunities for Seismic Risk Reduction



Additional Opportunities for Seismic Risk Reduction

1. Responding to Occupant Concerns
   - Track staff and patient concerns related to earthquake vulnerability, as a source of influence
2. Emergency Mngmt./Response Planning
   - Establish a liaison with emergency management agencies and volunteer organizations
3. Emergency Mngmt./Mitigation Planning
   - Incorporate hospital building seismic mitigation into the state mitigation plan

Additional Opportunities for Seismic Risk Reduction

4. Developing a Risk Reduction Policy
   - The Board of Directors should adopt a policy statement supporting seismic risk reduction.
5. Incorporating Federal & State Mandates
   - Become familiar with applicable requirements imposed on hospitals by federal and state programs
6. Coordinating with Risk & Insurance Managers
   - Establish coordination between facility management and risk management functions in the organization

Additional Opportunities for Seismic Risk Reduction

7. Becoming Familiar with Applicable Codes
   - Become familiar with any code-imposed seismic rehabilitation requirements. Code triggers may occur in "normal" remodeling projects.
8. Establishing and Maintaining a Roster of Design Professionals & Contractors
9. Negotiating Code Enforcement
   - Negotiate with code enforcement authorities an optimization of life safety and risk reduction when undertaking seismic rehabilitation

Additional Components of an Earthquake Safety Program

1. Building Contents Mitigation
   - Fastening laboratory equipment
   - Anchoring file cabinets, storage shelves, and other large furnishings
   - Restraining objects on shelves
   - Securing the storage of hazardous materials

Resource: FEMA E-74

Additional Components of an Earthquake Safety Program

2. Earthquake Drills
   - Influx of patients and casualties
   - Building damage

FEMA and Other Resources for Seismic Rehabilitation

- FEMA 396, Incremental Seismic Rehabilitation of Hospital Buildings
- ASTM E 2026, *Standard Guide for the Seismic Risk Assessment of Buildings*
- FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition*
- ASCE 31, *Seismic Evaluation of Existing Buildings*
- ASHE Management Monograph #055920, *Hazard Vulnerability Analysis*
- ASCE 41, *Seismic Rehabilitation of Buildings*
- FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage; A Practical Guide*
- FEMA 547 Techniques for Seismic Rehabilitation

Questions?

Earthquake Mitigation for Hospitals: Workshop

Part 8 – Building Mitigation

Structural Mitigation

RISK = f(HAZARD, VULNERABILITY)

Structural Mitigation Outline

- Building Mitigation options
- Challenges unique to hospitals
- Structural Mitigation tools and resources
- Structural Mitigation measures for buildings
- Examples of structural strengthening of buildings

Earthquake Losses

- Direct Damage:
  - Physical asset damage
  - Repair and restoration costs
- Indirect Damage:
  - Loss of facility operations
  - Loss of service to the community in the time of greatest need
  - Loss of Good Will
  - Patient evacuation/relocation
  - Loss of life

Earthquake Mitigation

- Mitigation of earthquake damage – Where to begin?
- Questions to ask and answer before any actual mitigation or major strengthening measures can be performed:
  - What is your facility/site risk?
  - What are your critical operations/functions that require protection?
  - What back-up/redundancy capabilities are available, and can they be relied upon?

Earthquake Mitigation

- Existing facility risk must be known
- Initial Facility Risk Assessment:
  - Desk-top survey $
  - Rapid visual survey of the facility $$
  - Comprehensive facility engineering risk assessment of building and nonstructural components $$$
- Rank & Prioritize the risks also considering critical functional aspects and long-term use of the facility.
- Develop a Mitigation Plan (FEMA 396) from the assessment findings and recommendations.
- Capitalize and begin to implement the Mitigation Plan.

Remember – reducing earthquake risk cannot be achieved overnight. Earthquake Mitigation is a long term process.

Earthquake Mitigation Options

- Do nothing – ignore the risk
- Accept the risk
- Modify emergency response & business recovery plans
- Adjust business operations:
  - Relocate critical functions to lower risk facilities
  - Locate non-critical functions to higher facilities
- Perform facility strengthening
- Perform nonstructural component strengthening and anchorage improvements
- Combination of the above

Earthquake Mitigation

- *Do it right the first time from today forward*
- *Long-term strategy:*
  - New Construction
  - Planned facility outages
  - Renovations & remodels
  - New equipment installations
  - Aging equipment replacement
  - During equipment maintenance activities
- *Earthquake mitigation does not happen overnight*

Hospital Mitigation Challenges

- Disruption to operations
- Loss of space
- Temporary relocation of patients and patient care services
- Specialized areas
  - MRI, X-ray, etc.
  - Pharmacies
  - Bio Hazards
  - Records
- Deep foundations

Hospital Challenges (Cont.)

- Interstitial (above ceiling) spaces

Hospital Challenges (Cont.)

- Typically congested mechanical & electrical rooms

Hospital Challenges (Cont.)

- Construction process:
  - Inherently a dirty environment
  - Noisy
  - Impact on building systems
    - Coordination with necessary system outages
    - Air filtration impact from dust & debris
    - Medical air and gases
    - Outside utility reliability during construction

Structural Mitigation Measures

- Member strengthening
  - New reinforcing steel and concrete encasement
  - Carbon-fiber wraps

Structural Mitigation Measures (Cont.)

- Connection strengthening
  - Simple bolting/welding and clips
  - Complex connection detailing

Structural Mitigation Measures (Cont.)

- Addition of new lateral force resisting systems
  - Construction of new concrete shear walls
  - Construction of new steel braced frames

Structural Mitigation Measures (Cont.)

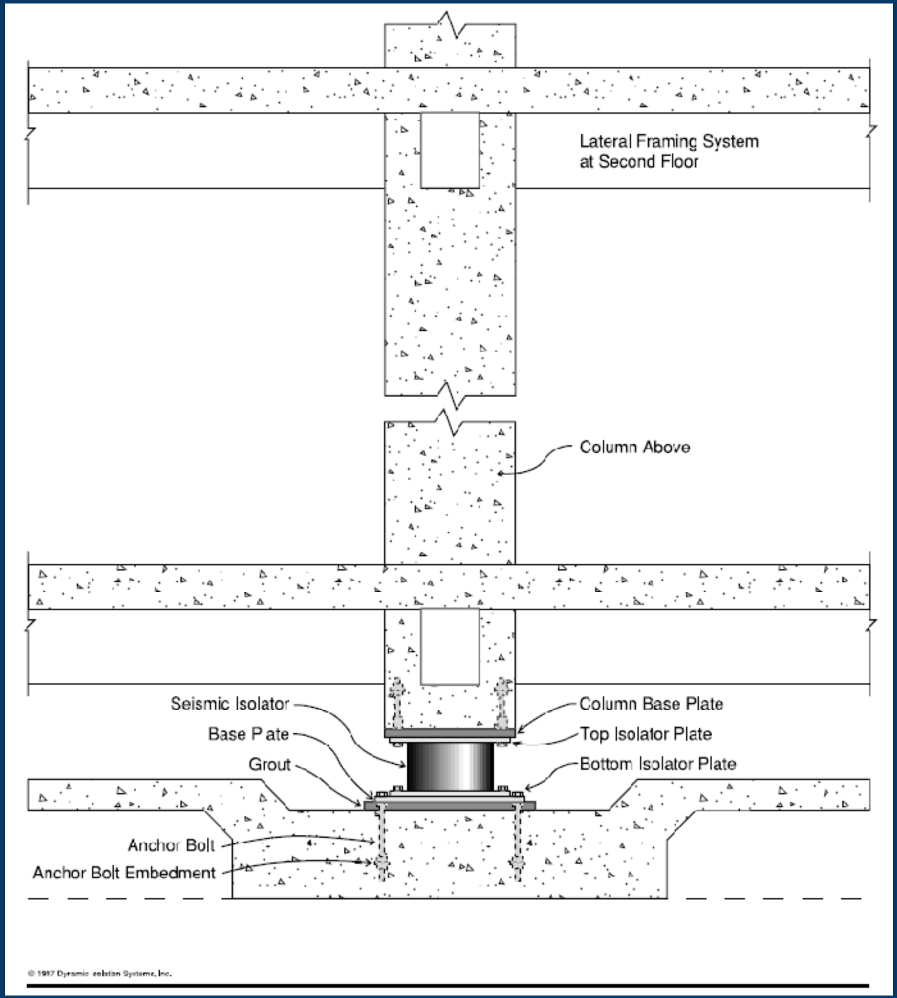
- Foundation strengthening

Specialized Mitigation Systems

- Energy dissipation devices – Braced frame viscous damper systems

Specialized Mitigation Systems (Cont.)

- Base Isolation of entire building



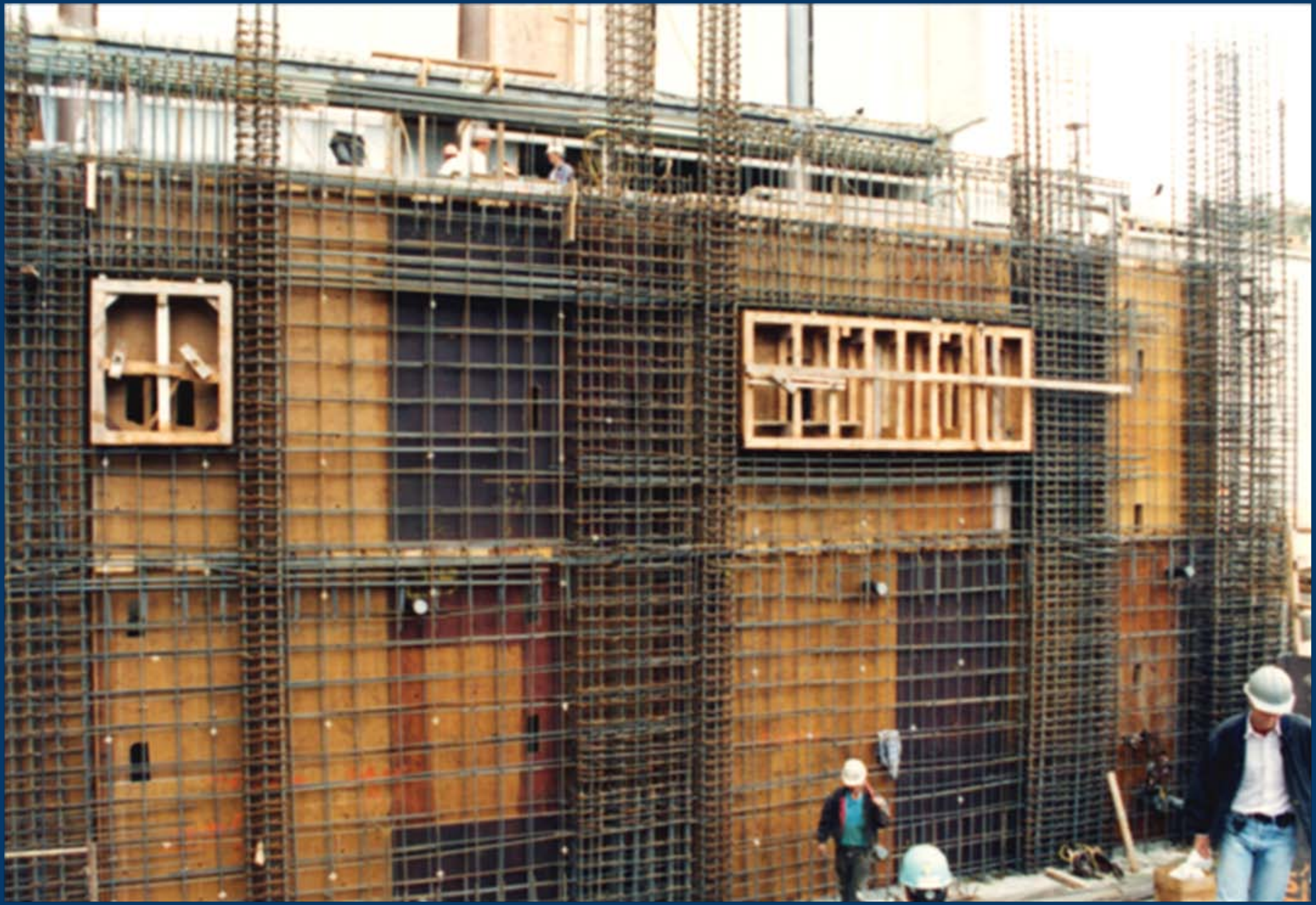
Mitigation Examples

Kaiser San Francisco Medical Center Seismic Strengthening

- Originally built in 1952 in three stages
- 7-Story concrete & steel frame
- 250,000 sq ft
- Function:
  - Nursing Units
  - Surgery Suites
  - Emergency Room
  - Laboratories

Kaiser San Francisco Medical Center

Kaiser Medical Center Shear Wall Construction



Kaiser Medical Center Elevator Shaft Construction

Kaiser Medical Center Foundation Strengthening

Veterans Administration West Los Angeles Medical Center

- Seismic evaluation and retrofit of (3) Campus Buildings
- 6-Story Main Medical Center under design
- Existing structure - Steel braced frame
- 900,000 sq ft
- Exterior steel braced frames being used to minimize disruption to VA operations

VA Medical Center Rendering

VA Medical Center

St. Vincent Medical Center
Los Angeles

- Detailed risk assessment and preliminary strengthening design being performed
- Assessing current and future facility needs
- Addressing California SB 1953 compliance
- Construction documents developed for SB 1953 NPC 2 deficiencies

St. Vincent Medical Center Earthquake Strengthening

Stanford University Hoover Pavilion

- 1930's Vintage
- Six-story concrete shear wall structure
- Originally an acute care hospital
- Current facility function is:
  - Outpatient services
  - Medical office facilities
- Seismic strengthening incorporated with a planned infrastructure renovation
- Facility remained operational during construction

Hoover Pavilion Strengthening

UC San Francisco MSB/Moffit

- 15-story Moffitt Hospital
- 15-story Medical Sciences Building
- Buildings seismically separated for compliance with SB 1953 requirements
- Strengthening schemes designed to separate the buildings
- New exterior stair options were incorporated into the project

UC San Francisco Separation Strengthening Project

Veterans Administration American Lake Tacoma, WA

- Mental Health Patient Care facility
- 1932 Vintage
- 3-story concrete frame
- 51,000 sq ft
- Seismic strengthening scheme:
  - Exterior concrete shear walls
  - Objective to minimize disruption to the facility

VA American Lake

Summary Earthquake Mitigation

- *Do it right the first time from today forward*
- *Long-term strategy:*
  - New Construction
  - Planned facility outages
  - Renovations & remodels
  - New equipment installations
  - Aging equipment replacement
  - During equipment maintenance activities
- *Earthquake mitigation does not happen overnight*

Questions?

Earthquake Mitigation for Hospitals: Workshop

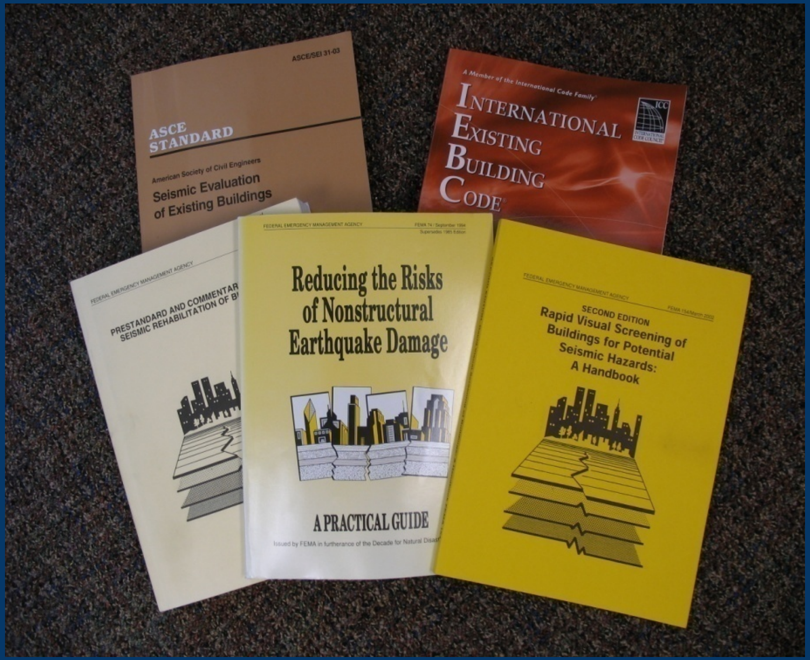
Part 9 – Nonstructural Equipment Mitigation

Nonstructural Mitigation Options

- Retrofit
- Replace
- Relocate
- Replicate (redundancy N+1/ provide a back-up)
- Plan for the consequences of failure

Nonstructural Resources

- FEMA 74 – Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide
- FEMA 154/155 – Rapid Visual Screening of Buildings for Potential Seismic Hazards
- ASCE/SEI 31-03 – Standard Seismic Evaluation of Existing Buildings
- ASCE 41-06 – Seismic Rehabilitation of Existing Buildings



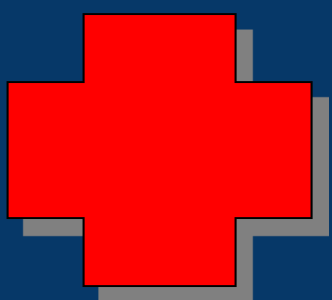
Nonstructural Resources

- FEMA 412: Installing Seismic Restraints for Mechanical Equipment
- FEMA 413: Installing Seismic Restraints for Electrical Equipment
- FEMA 414: Installing Seismic Restraints for Duct and Pipe

Nonstructural Mitigation

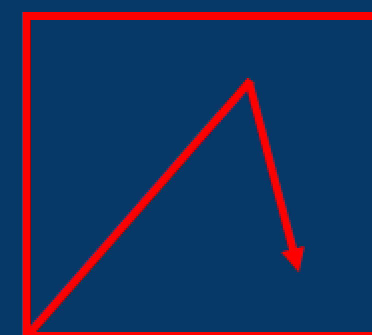
Nonstructural Mitigation

Step 1 – Risk Assessment



Life Safety

Property Loss



Functional Loss

Life Safety

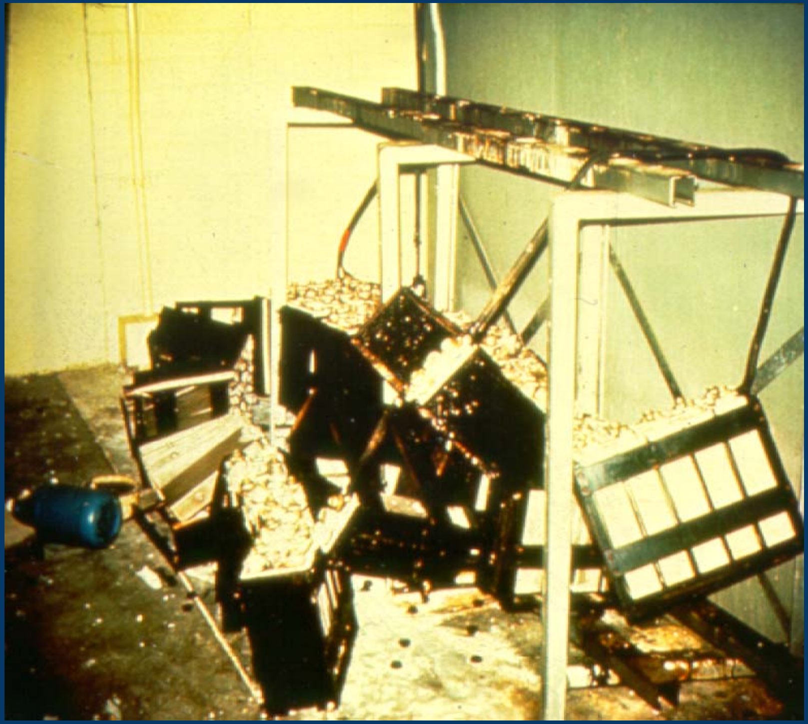
If item is damaged and inoperable will it:

- Become dislodged and hurt someone?
- Interrupt life support equipment?
- Harm patient's health?
- Prevent ability to perform emergency room services? Operating room services? Other critical care services?
- Require patients to be transferred?

Can it hurt someone?

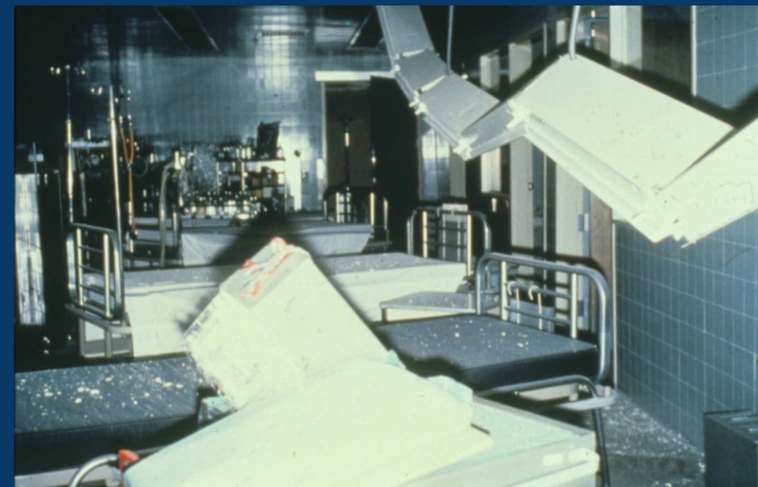
Can it hurt someone?

Can it interrupt life support?



Can it harm patient's health?

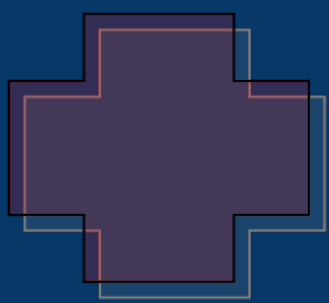
Prevent ability to provide critical care services?



Require evacuation?

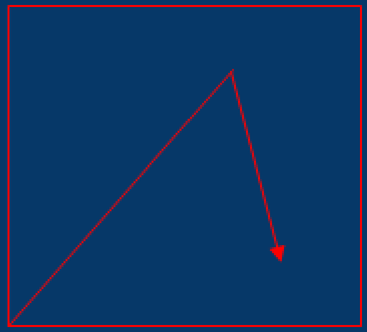
Nonstructural Mitigation

Step 1 – Risk Assessment



Life Safety

Property Loss



Functional Loss

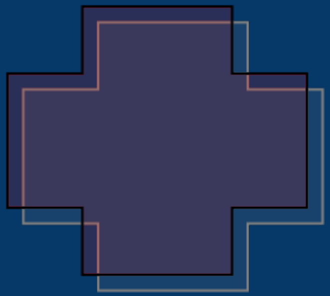
Property Loss

Repair or replacement of:

- Equipment
- Interior finishes
- Exterior cladding

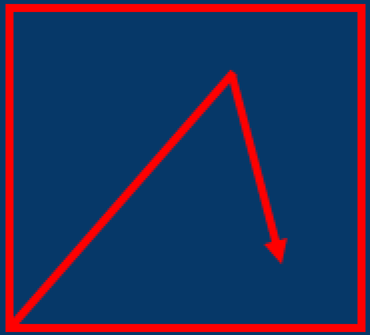
Nonstructural Mitigation

Step 1 – Risk Assessment



Life Safety

Property Loss



Functional Loss

Functional Loss

Nonstructural Mitigation Steps

1. Facility risk assessment:
   - Desk-top survey — $
   - Rapid visual survey of the facility — $$
   - Comprehensive facility risk assessment of building and nonstructural components — $$$

2. Rank & prioritize risks

3. Develop a Mitigation Plan from the assessment findings and recommendations

4. Capitalize and begin to implement the Mitigation Plan

FEMA 74 nonstructural assessment

NONSTRUCTURAL INVENTORY SURVEY FORM

Building Name _Corporate Headquarters_______________ Inspector __Joe Engineer______________________

Address __5555 Kingshighway____ Date __April 19, 2007________

City, State Zip __Anywhere, USA____

Room ID	Element Description	Quantity	Units	Restraint Detail	Retrofit Required Y/N	Comments
501	Administrative Offices:					
	Suspended Ceiling	1	144 sf	Detail ES-4	Y	Attach perimeter grid to (2) adj. walls.
	2x4 Fluorescent Lights	6	- - -	Detail ES-24	Y	Add safety wires to lights – One each opposite corner.
	Bookcases at exit	2	- - -		Y	Relocate bookcases from egress corridor, or anchor to adjacent wall studs per Detail ES-5.
502	Electrical Room:					
	Dry-Type Transformer	1	- - -	Detail ES-32	Y	Anchor unanchored transformer.
	Automatic Transfer Switch Panel	1	- - -	Detail ES-36	Y	
	Telecom/Network Racks	2	- - -		N	Rack bases are well anchored.
	Electric Bus Duct	1	- - -		N	Well braced top & bottom.

Sheet _____ of _____

Earthquake Hazard Mitigation for Nonstructural Elements Nonstructural Inventory Survey Form

Identifying Nonstructural Hazards

Ceilings

Lights

Partitions

Identifying Nonstructural Hazards

- Nuclear medicine equipment
  - Suspended
  - Floor-mounted
- Ceilings
- Overhead lights
- Suspended piping

Identifying Nonstructural Hazards

- Ice Maker
- Med Stations
- Wall-mounted monitors
- Ceiling
- Overhead lights
- Suspended piping

Identifying Nonstructural Hazards

- Sterilizers
- Storage cabinets
- Mobile carts
- Casework
- Ceilings
- Overhead lights
- Suspended piping

Identifying Nonstructural Hazards

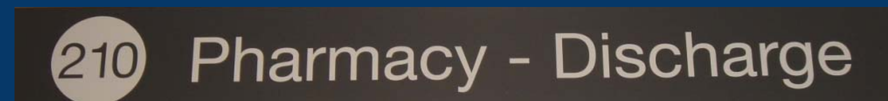
- Contents
- Storage racks
- Shelves
- Overhead lights
- Suspended piping

Identifying Nonstructural Hazards

- Refrigerators
- Analyzers
- Bench top equipment
- Storage cabinets
- Bookcases
- Ceilings
- Overhead lights
- Suspended piping

Identifying Nonstructural Hazards

- Cabinets
- Casework
- Ceiling
- Overhead lights
- Suspended piping



Identifying Nonstructural Hazards

- OR lights
- Equipment booms
- Film viewers
- Monitors
- Ceiling
- Suspended piping and HVAC

Operating Rooms

Identifying Nonstructural Hazards

- Monitors
- Headwall
- Casework
- Storage cabinets
- Televisions
- Ceiling
- Suspended piping

ICU

Identifying Nonstructural Hazards

Radiology

- Radiology equipment
- Casework
- Storage cabinets
- Ceiling
- Suspended piping

Identifying Nonstructural Hazards

- Boilers
- Chillers
- Tanks
- Cooling Towers
- Air handlers
- Exhaust fans
- Fan coils
- Piping
- Ductwork

Mechanical

Identifying Nonstructural Hazards

- Generators
- Motor control equipment
- Switchgear
- Transformers
- Panel boards
- Conduit
- Bus duct

Electrical

Identifying Nonstructural Hazards

- Continuous piping
- Continuous conduit
- Partitions

Building Separations

Identifying Nonstructural Hazards

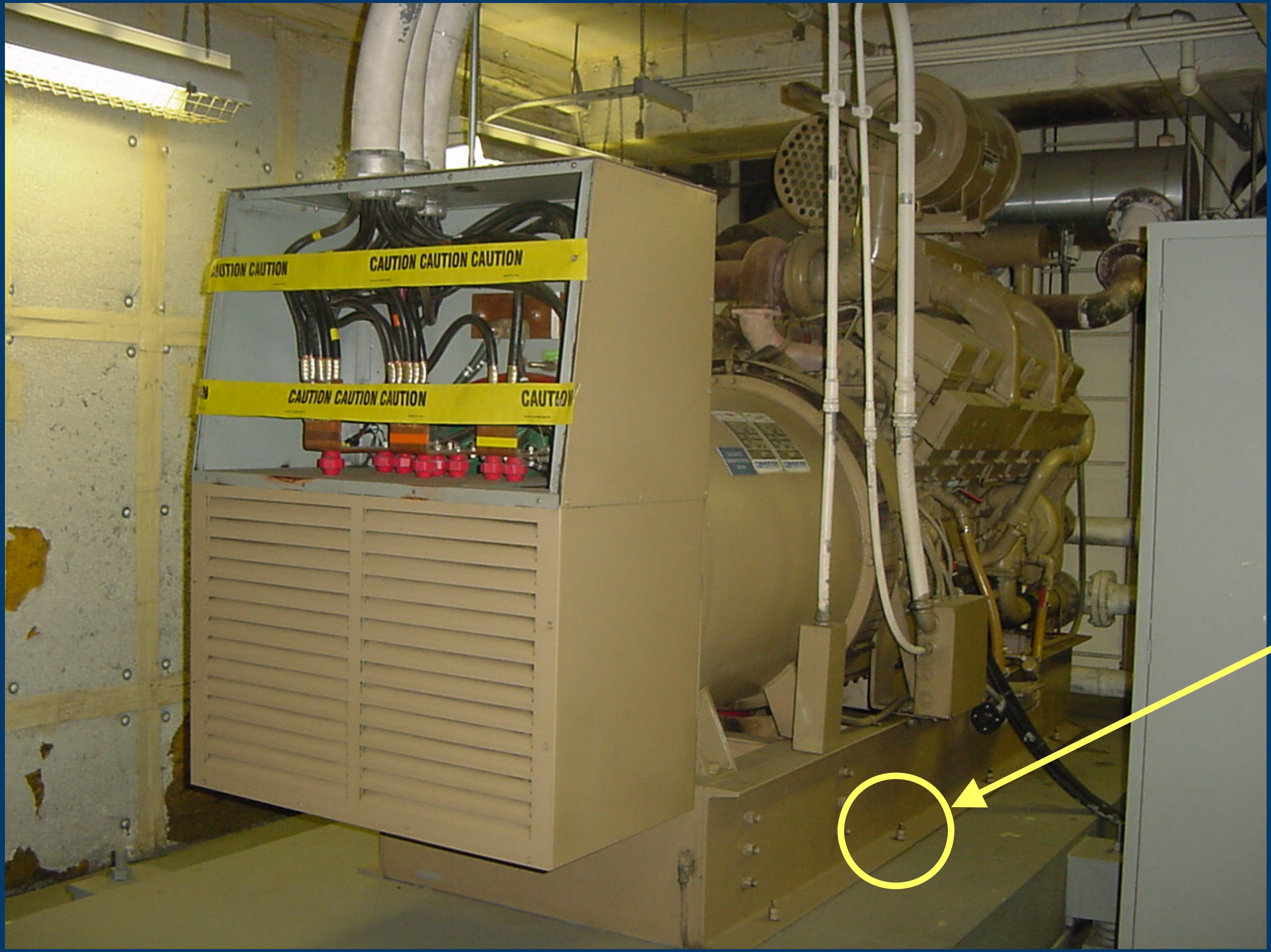
Exterior

- Cladding
- Parapets
- Glazing
- Signs
- Canopies

Mitigating Nonstructural Risks

- Building utility systems
- Architectural elements
- Medical equipment
- Furniture and contents

Emergency Generator

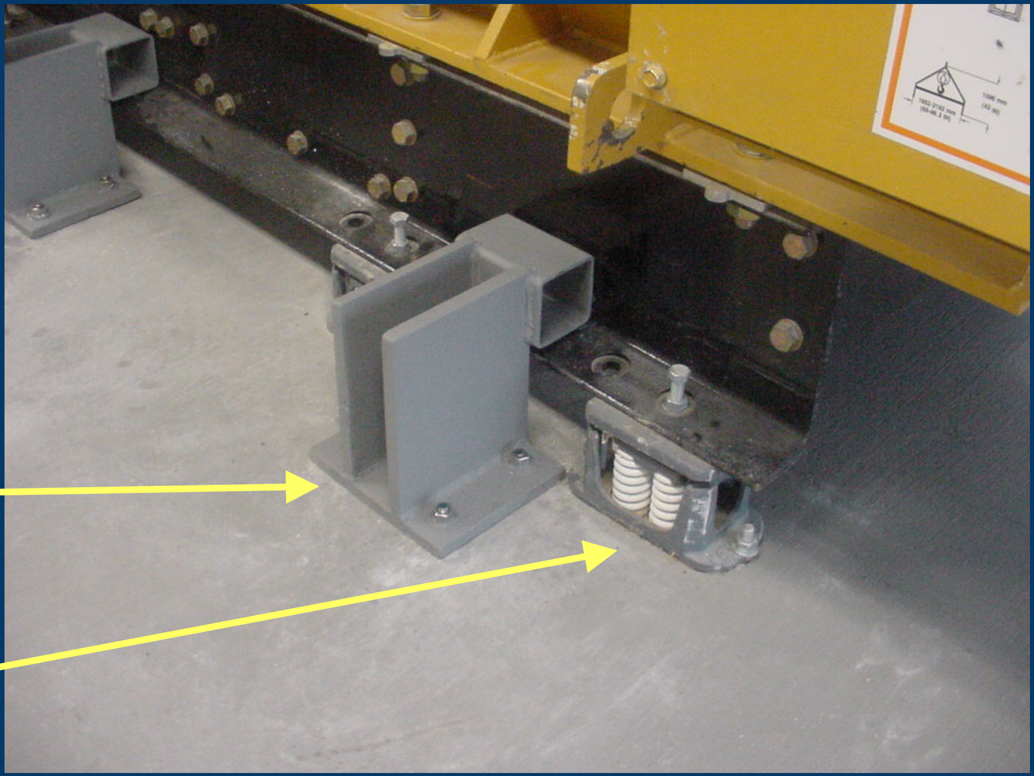


Anchor Bolt

Emergency Generator

Seismic Strengthening

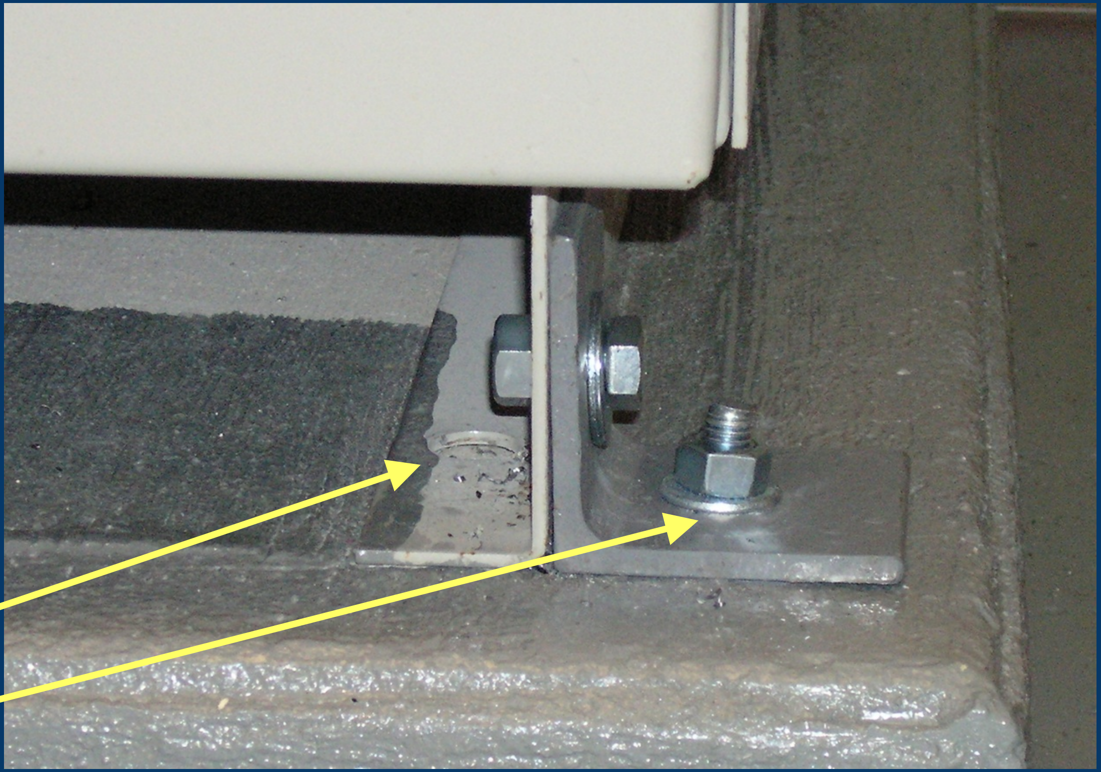
Non-seismic isolators



Emergency Generator

Seismic chain restraints

UPS Battery Cabinet



Missing anchor

Seismic retrofit

Packaged Chiller Unit

Seismic Strengthening

Non-seismic base isolators

Instrument Air Compressor

Base Strengthening

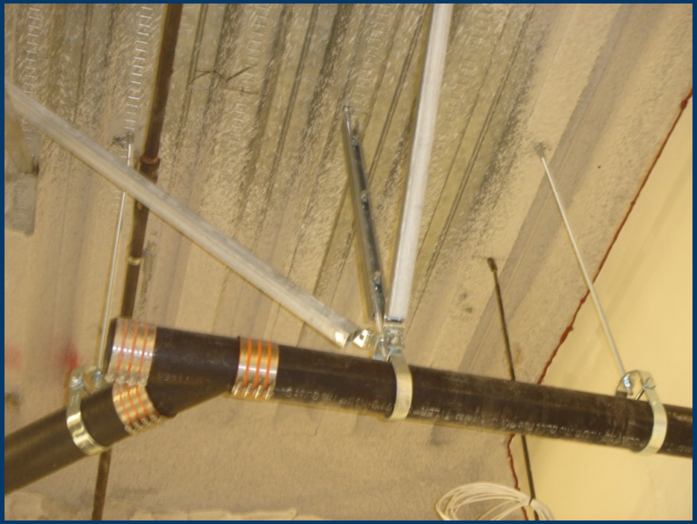
Fuel Oil Storage Tank

Additional Base Strengthening

Fuel Oil Day Tank

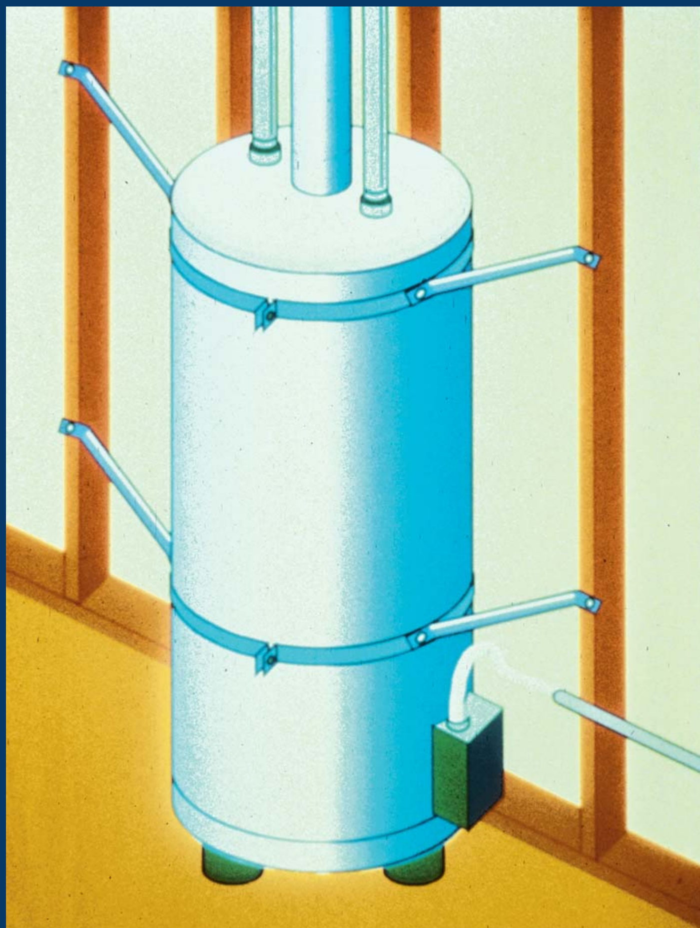
Marginal strengthening measure using seismic strap. Note large gap at wall and absence of base anchorage.

Suspended Piping



Suspended Conduit

Gas Hot Water Heaters



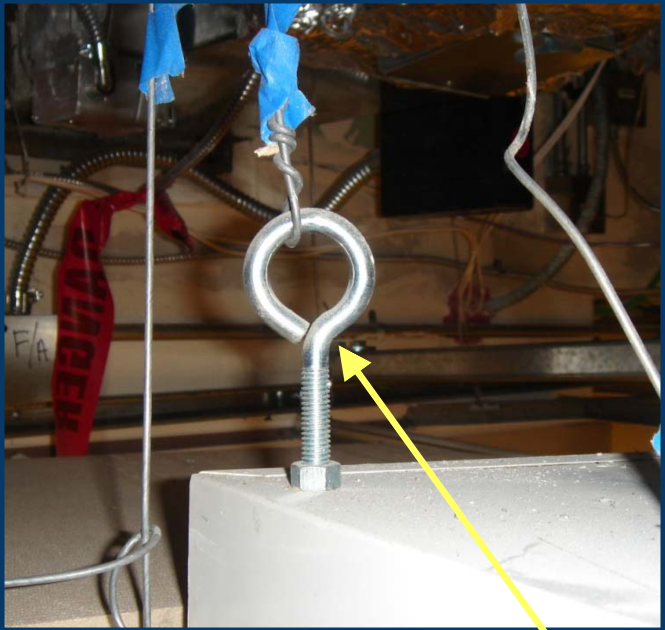
Architectural Elements

Ceilings

Compression post and splayed wire bracing

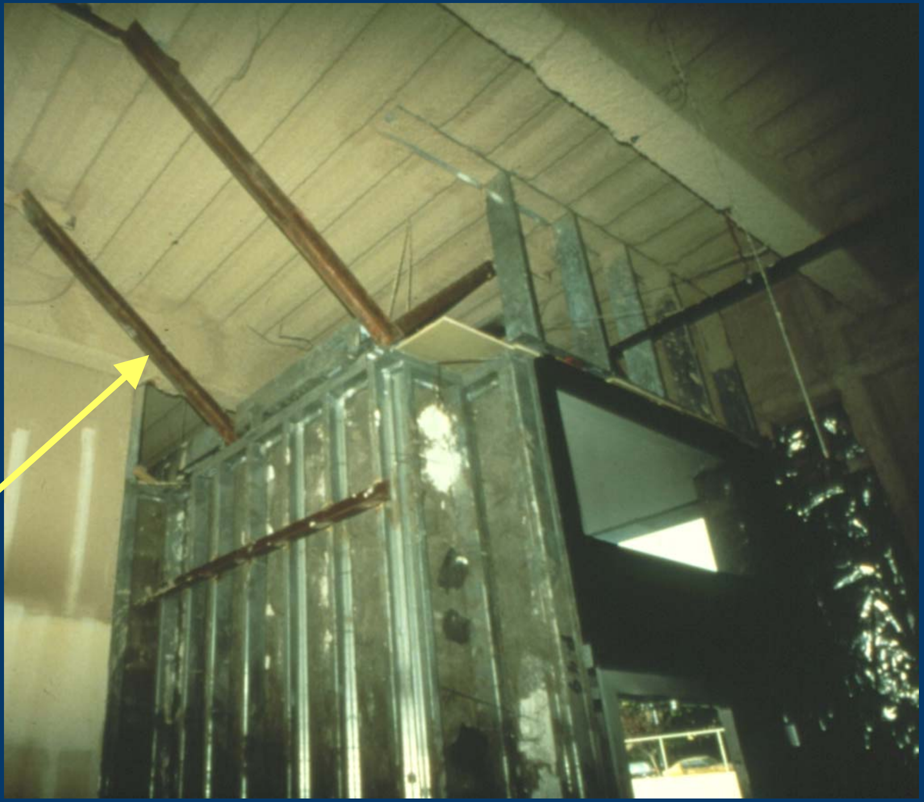
Proper grid attachment at walls

Lights



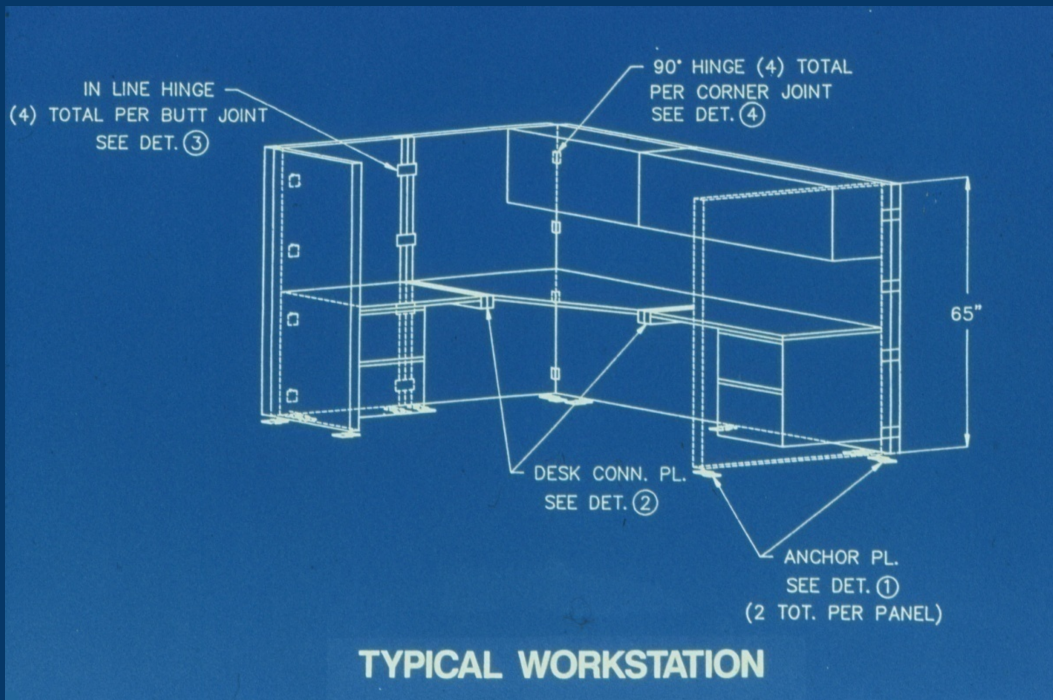
Independent support at two diagonally opposite corners

Partitions

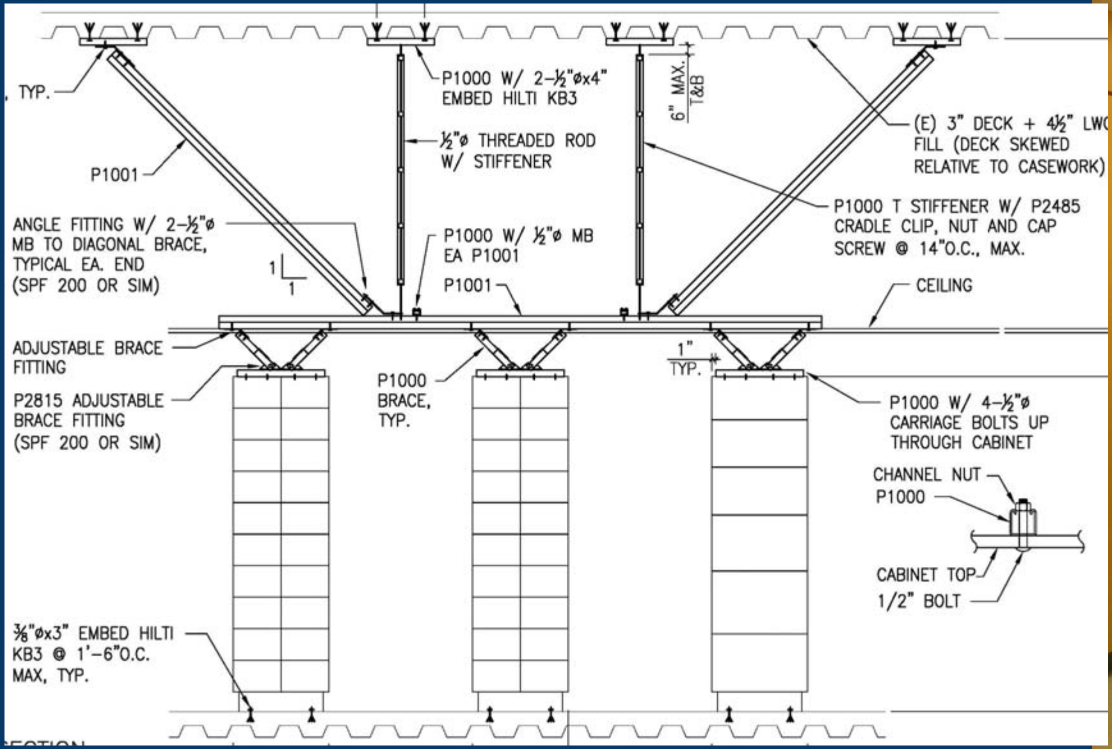


Added bracing at top of partial height studs

Demountable Partitions



Shelving



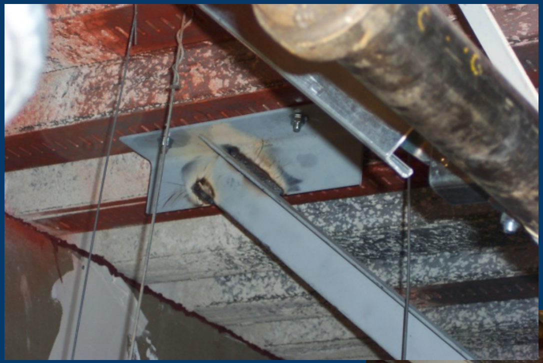
TYP.
P1001
P1000 W/ 2-½"ø x4" EMBED HILTI KB3
½"ø THREADED ROD W/ STIFFENER
6" MAX. T&B
(E) 3" DECK + 4½" LWC FILL (DECK SKEWED RELATIVE TO CASEWORK)
P1000 T STIFFENER W/ P2485 CRADLE CLIP, NUT AND CAP SCREW @ 14"O.C., MAX.
ANGLE FITTING W/ 2-½"ø MB TO DIAGONAL BRACE, TYPICAL EA. END (SPF 200 OR SIM)
P1000 W/ ½"ø MB EA P1001
P1001
CEILING
ADJUSTABLE BRACE FITTING
1" TYP.
P2815 ADJUSTABLE BRACE FITTING (SPF 200 OR SIM)
P1000 BRACE, TYP.
P1000 W/ 4-½"ø CARRIAGE BOLTS UP THROUGH CABINET
CHANNEL NUT
P1000
CABINET TOP
1/2" BOLT
⅜"ø x3" EMBED HILTI KB3 @ 1'-6"O.C. MAX, TYP.

Cabinets

Refrigerators

Operating Room Lights

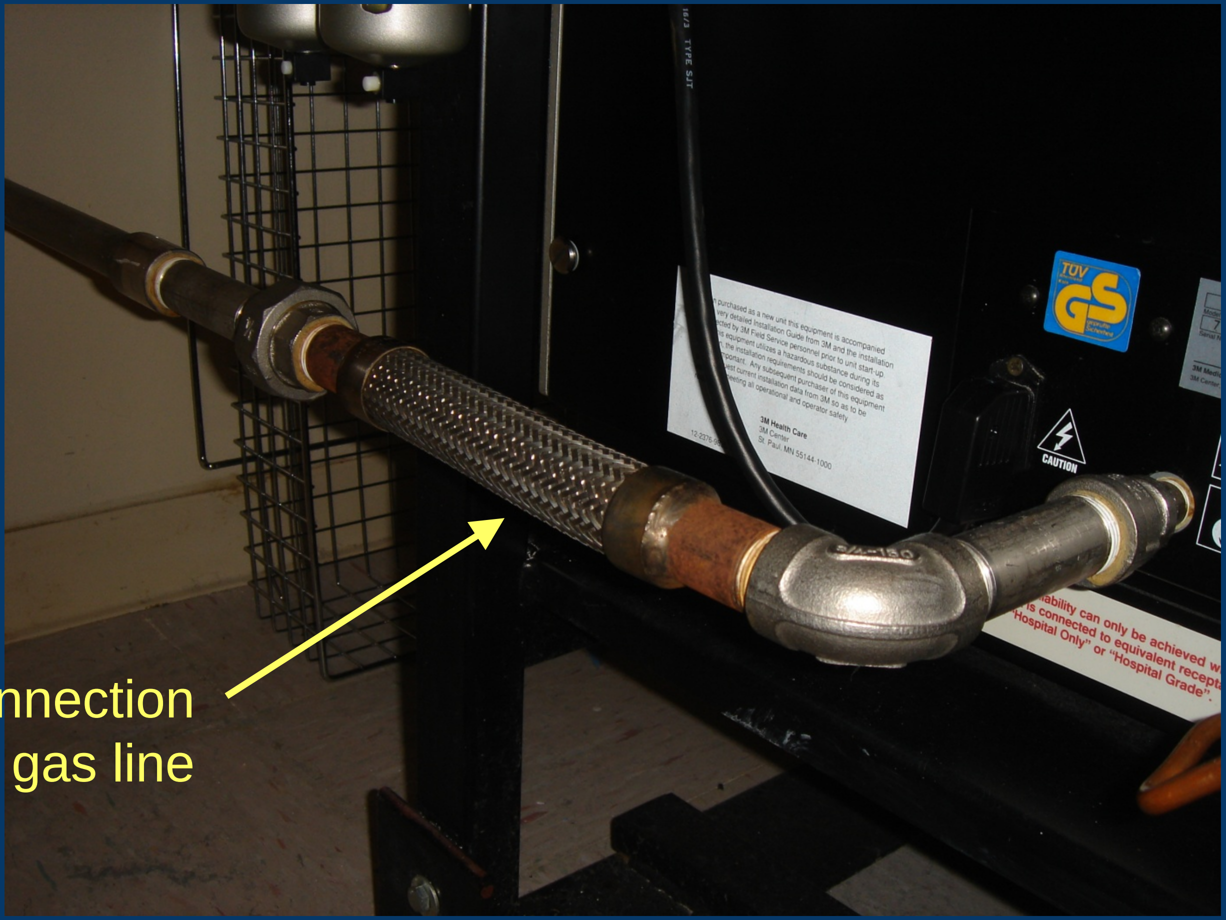
Operating Room Lights



Mobile Carts

Sterilizer

Sterilizer



Flexible connection in gas line

Televisions

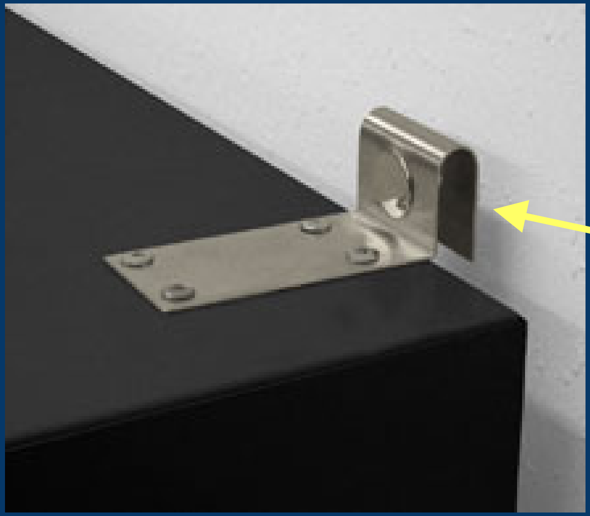
Televisions

Televisions

Bench, Rack, or Table-Top Restraints

Bench, Rack, or Table-Top Restraints

Furniture/Shelving Content Restraints



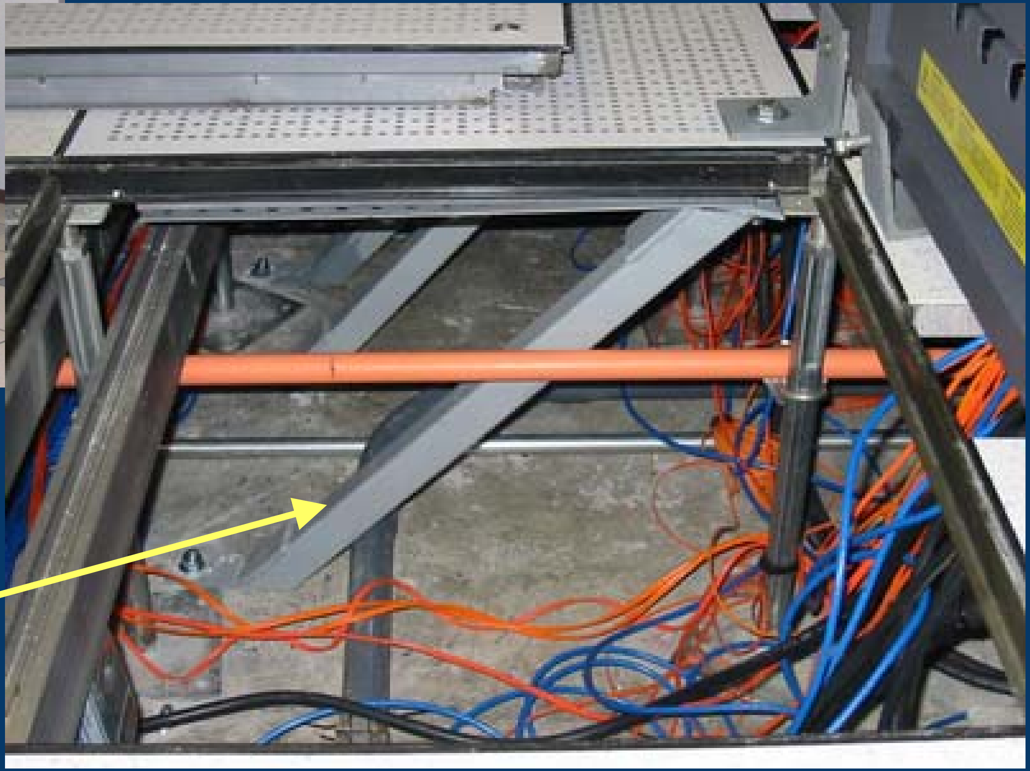
Small Equipment Base Anchorage

Shelving Part Container Restraints

Furniture Restraints

Typical Product Restraints

Computer Equipment



Raised floor bracing

Equipment Anchorage

Implementation

Biggest challenges of nonstructural mitigation in a hospital:

1. 24/7
2. No swing space
3. Infection control
4. Hazardous materials

Patient Care Areas

Patient Care Areas

Patient Care Areas

Best Long Term Strategy

New Construction:

Do it right the first time

Remodel:

Take care of problems when you have the chance

Earthquake Mitigation for Hospitals: Workshop

Part 10 – Integration Opportunities

Integration Opportunities for Structural and Nonstructural Mitigation

Categories of Hospital Maintenance and Capital Improvement Projects

1. Patient Care Improvements
2. New Technology Accommodation
3. Fire and Life Safety Improvements
4. Roofing Maintenance and Repair
5. Exterior Wall and Window Maintenance/Facade Modernization

Integration Opportunities for Structural and Nonstructural Mitigation

Categories of Hospital Maintenance and Capital Improvement Projects

6. Underfloor and Basement Maintenance & Repair
7. HVAC Improvements
8. Energy Conservation / Weatherization
9. Hazardous Materials Abatement
10. Building Additions

Integration Opportunities for Structural and Nonstructural Mitigation

Examples From FEMA 396

Table C-1: Patient Care Improvements

Number*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections				□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection				□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

Integration Opportunities for Structural and Nonstructural Mitigation

Examples From FEMA 396

Table C-1: Patient Care Improvements

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections				□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection				□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

Vertical Load Carrying Structure:

- Wood
- Unreinforced Masonry
- Reinforced Masonry
- Concrete
- Steel

Generalized Building Structure Earthquake Performance

Decreasing Vulnerability ↓

Stiff Structures	Flexible Structures
Unreinforced Masonry (Brick)	Concrete Precast Frame (Parking Garages)
Concrete Frame with URM Infill	Concrete Moment Resisting Frames
Concrete Tilt-Up	
Steel Frame w/URM Infill Shear Walls	
Reinforced Masonry	Steel Moment Resisting Frames
Concrete Shear Wall	Light Metal Frame Buildings
Steel Braced Frames	Wood Frame Buildings

Integration Opportunities for Structural and Nonstructural Mitigation

Examples From FEMA 396

Table C-1: Patient Care Improvements

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
	L	M	H				Wood	Masonry[1]		Concrete		Steel	
								Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓		All		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections				□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection				□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

Structural Improvements

- Foundations
- Horizontal Elements
- Vertical Elements

Structural Mitigation

- Member strengthening
- Connection strengthening
- Addition of new Lateral Force-Resisting Systems
- Foundation strengthening

Integration Opportunities for Structural and Nonstructural Mitigation

Examples From FEMA 396

Table C-1: Patient Care Improvements

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✔	✔	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
[illegible]		✔	✔	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✔	✔	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✔	✔	✔	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✔	✔	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✔	✔	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✔	✔	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✔	✔	✔	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✔	✔	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✔	✔	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✔	✔	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✔	✔	✔	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✔	✔	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✔	✔	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✔	✔	All		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✔	✔	Foundation		Anchor Bolts	■						
n/a		✔	✔	Foundation		Cripple Stud Bracing	■						
n/a		✔	✔	Foundation		New Foundations	■						
n/a		✔	✔	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✔	✔	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✔	✔	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a	✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Capacity/Stiffness				□	☒	□	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Continuity				□	☒	□	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Connections				□	□	□	□
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness				□	☒	□	☒
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Connection				□	□	□	□
n/a		✔	✔	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✔	✔	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✔	✔	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✔	✔	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✔	✔	✔	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

Nonstructural Improvements

Integration Opportunities for Structural and Nonstructural Mitigation

- Building Utilities
- Architectural Components
- Medical Equipment
- Furniture and Contents
- Communications / IT Systems

Integration Opportunities for Structural and Nonstructural Mitigation

- Building Utilities
  - Patient Care Improvement
  - Lighting/Electrical
  - Fire Extinguishing System
  - Mechanical and Plumbing Systems
  - Boilers

Integration Opportunities for Structural and Nonstructural Mitigation

- Architectural Components
  - Ceilings
  - Partitions
  - Cladding
  - Access Floors
  - Canopies

Integration Opportunities for Structural and Nonstructural Mitigation

- Medical Equipment
  - X-Ray and Scanning Devices
  - Cabinets and Storage
  - Refrigerators
  - Benchtop Equipment

Integration Opportunities for Structural and Nonstructural Mitigation

- Furniture and Contents
  - Storage racks
  - Shelving
  - File Cabinets
  - Bookcases

Integration Opportunities for Structural and Nonstructural Mitigation

RISK = f (HAZARD, VULNERABILITY)

Risk is a function of both the potential hazard (seismic ground motion) and vulnerability (lack of seismic preparedness in structural and nonstructural systems)

Questions?

Earthquake Mitigation for Hospitals: Workshop

Part 11 – Conclusions

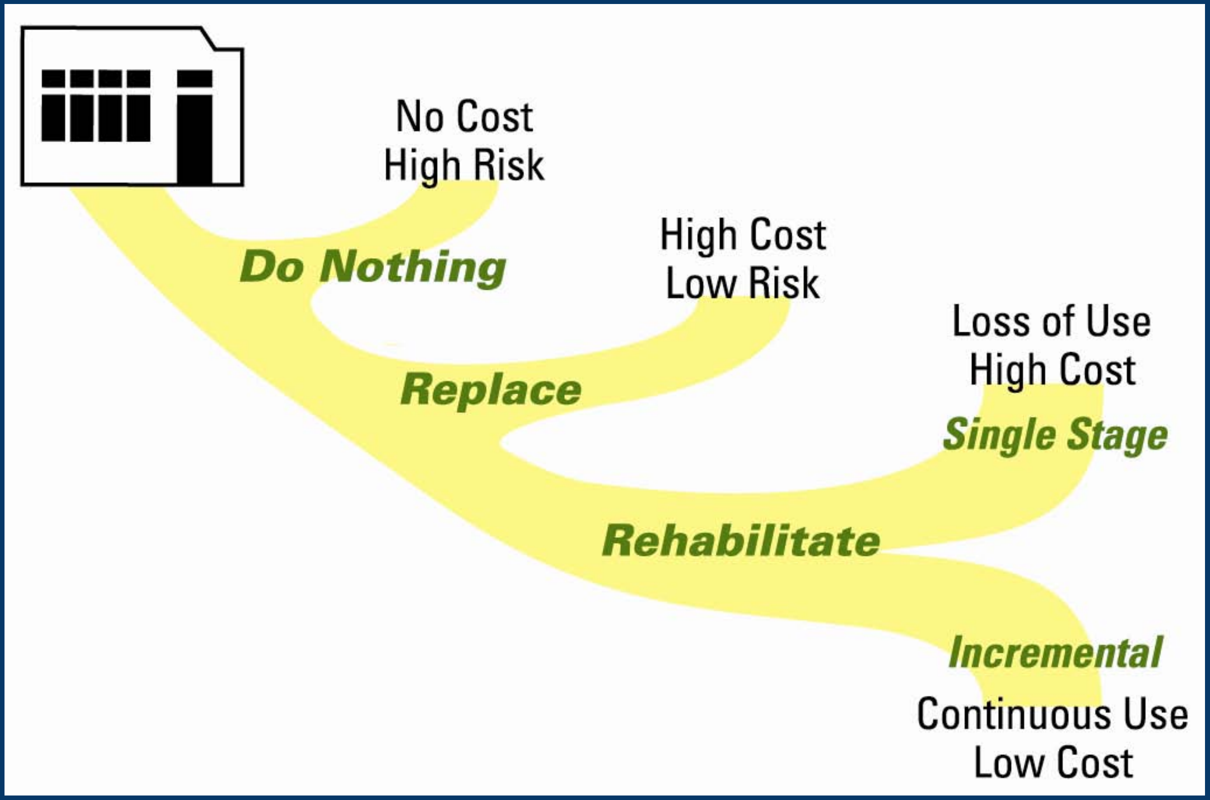
Summary

- What did we learn today?
  - Vulnerability assessment
  - Planning for mitigation
  - Implementing mitigation
  - Integration opportunities

Developing a Look Ahead or Long-Term Strategy

- New construction
- Rehabilitation/Integration
- New equipment installation
- Equipment replacement
- Maintenance activities

Overview of Seismic Risk Reduction



Actions

- What activities will you do tomorrow using the knowledge gained in this workshop?

Questions?

Feedback Survey Forms