ATC-58 Development of Performance-Based Seismic Design Guidelines

Proceedings: Mini-Workshop/Invited Meeting on the Identification of Nonstructural Components of Significance

Project: ATC-58 Development of Next Generation Performance-based Seismic Design Guidelines

Attendees: *Project Steering Committee*: W. Holmes (chair), J. Gillengerten
Project Management Committee: R. Hamburger, M. Phipps, C. Rojahn, J. Heintz
Product Development Teams: R. Bachman, A. Whittaker, C. Comartin, E. Miranda, K. Porter, G. Hecksher
FEMA: R. Hanson, J. Lusk
Invited Participants: T. Anagnos, H. Blecher, M. Comerio, J. Eidinger, J. Ferritto, B. Gates, B. Reitherman, S. Swan

Location: Simpson Gumpertz & Heger Inc., San Francisco, California

Date: August 25, 2005

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Description</th><th colspan="2">Action</th></tr>
<tr><th>Responsible</th><th>Date Due</th></tr>
<tr><td>1.</td><td>Opening Remarks: Bachman welcomed workshop participants, provided an overview of the workshop purpose, reviewed the agenda, and asked for self-introductions (Attachment A).

The reason for the workshop was to assist the project team in identifying the nonstructural components and systems which are significant in the overall seismic performance of building structures. Invited participants were experts in the field of seismic losses associated with nonstructural component and systems. For the ATC-58 Project, performance is measured in one of three ways: (1) casualties; (2) cost of repair and replacement; and (3) downtime and consequential damages. Since there are a tremendous number of nonstructural components and systems in a typical building, it is extremely valuable to recognize only those components and systems which are really important to one or more of these performance measures and to group the rest into large categories (bins) which are not significant to the performance measures. In assessing performance, the ATC-58 Project is currently considering the following 8 occupancy types:

1. Commercial Office
2. Education
3. Healthcare
4. Hospitality</td><td></td><td></td></tr>
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	5. Residential 6. Research 7. Retail 8. Warehouse The special needs of these occupancies were to be considered in determining which nonstructural components are important for estimating casualties, dollar loss, and downtime. A NISTIR 6389 taxonomy of components present in a building was used to focus the discussion in the workshop.		
2	**Overview of ATC-58**: Hamburger provided an overview of the ATC-58 Performance-Based Seismic Design Project (Attachment B). While focused on the seismic design problem, the methodology should be compatible with design for other hazards, including fire and blast. It is intended to address problems identified with first-generation performance-based design methods, including stakeholder difficulties in making decisions regarding minimum levels of acceptable performance, and needs for quantification of dollar loss and risk. The process will be kept as close as possible to current practice, user friendly, yet sufficiently precise for building-specific assessments.		
3	**Assessment Process**: Comartin provided an overview of the assessment process including a brief example on a sample project (Attachment C). Discussion: Components need to be categorized into performance groups with the following characteristics – each in one group only; occur at similar locations in the building; performance keyed to the same Engineering Demand Parameter; common fragility; similar impacts on loss. When dealing with components that are an assembly of items, fragility functions need to address the performance of the assembly, including connections. The methodology will include some “built-in” fragilities as well as protocols for developing user-specified fragilities. We may need multiple levels of performance groupings to adjust level of effort and aggregate or disaggregate results to make informed decisions about the design of specific components.		
4	**Nonstructural Components that matter**: Miranda provided an overview of the characteristics of nonstructural components that significantly affect loss estimation: (1) Components must commonly exist in the building class under consideration; (2) They must have a high consequence of damage in casualties, dollars, or downtime; and (3) Damage occurs at low Intensity Measures (Attachment D).		
5	**Comparison of Design Standards and Damage Assessment**: Comerio and Blecher presented a study comparing classification lists and damage assessment parameters from several sources including FEMA 356, SEAOC Vision 2000, and ATC-20 (Attachment E).		
6	**Performance of Nonstructural Systems**: Gates presented photographic examples of nonstructural component damage from past earthquakes (Attachment F).		
7	**Past Economic Analysis**: Ferritto presented an example of past economic analyses for seismic design of structural and nonstructural		

	components (Attachment G).		
8	**Past Data Points**: Reitherman presented comments on past data points related to reducing the risk of nonstructural damage (Attachment H). <u>Discussion:</u> Lists imply tasks. We need to prioritize our list of considerations to look at the most important things. We can't consider everything.		
9	**Building Component Taxonomy**: Porter defined the term "taxonomy", which is the process of classifying objects into established categories, and presented an overview of a modified NISTIR 6389 taxonomy for classifying all of the components in a building (Attachment I). Useful taxonomic categories have the following characteristics: 1. Clear (not circular) definitions 2. Common fragility 3. They distinguish performance (i.e. braced versus unbraced) 4. Testable, quantifiable fragilities 5. We can assess the consequences (casualties, dollars, downtime) 6. Flexible (allows incorporation of new information) 7. Collectively exhaustive 8. Simple 9. Collapsible (coarse levels, and more detailed levels) 10. Familiar terms (ease of communication between various user groups)		
10	**Nonstructural components discussion:** Bachman led a discussion through Porter's modified NISTIR 6389 taxonomy to collect and record expert opinion on which nonstructural categories are of significance in estimating casualties, dollar losses, and/or downtime. Based on the results of the discussion, an abbreviated list is contained in Attachment J. Certain components (canopies, marquees, and stairs) were set aside for further discussion on whether or not they should be classified as structural or nonstructural components. <u>Follow up:</u> In a teleconference on 8/31/05 it was agreed that these components would be treated as nonstructural components but that they should be included in the structural analysis model if they significantly affect the structural response of the building. The categories for piping and HVAC systems and equipment did not seem to be broken down in a way that was useful for performance assessment. The items in these categories were set aside to be reorganized in a new list prepared by Swan. <u>Follow up:</u> In subsequent correspondence on 9/2/05, Swan provided a list of possible classifications of HVAC and electrical system components with sample earthquake performance and fragility data (Attachment K).	Bachman, Whittaker, Comartin, Hamburger Swan	9/1/05
11	**Contents discussion**: Bachman led a discussion on building contents, such as furnishings and inventories, which are separate from nonstructural		

	components, but have some significance to performance assessment given the special needs of specific occupancies (see also Attachment J). Discussion: Some expressed a desire to be able to predict the quantity and extent of damage to contents of interest to stakeholders (i.e. – the number of computers that fall off desks, or the number of file cabinets that fall over). It was suggested, however, that the methodology is not intended to provide information to that level of specificity. The process will allow user-defined groups, with user-defined fragilities, but will contain built-in fragilities or assumptions about contents. An argument was made that building-specific assessments cannot be made with default information, and that assessment requires detailed inventories of actual building contents. Hamburger noted that beta values will change with the level of knowledge.		
12	Workshop adjourned at 5:00 pm		

ATC – 58 Mini-Workshop/ Invited Meeting on
The Identification of Non-Structural Components of Significance
August 25, 2005
Tentative Agenda – Rev 1

9:30 AM	Call Workshop to Order	Bob Bachman
	Purpose of Workshop/Meeting – Scope of Nonstructural	
	Why you were invited - What is goal for the day – HAZUS ?	
	Review of Agenda - House keeping items – lunch how/where	
9:45 AM	Self Introduction of Attendees	All
10:00 AM	ATC-58 Brief Project Overview	Ron Hamburger
10:10 AM	Brief Overview of the Performance Assessment Process	Craig Comartin
10:20 AM	Presentation by Eduardo Miranda	
10:30 AM	Presentation by Mary Comerio	
10:40 AM	Presentation by Bill Gates	
10:50 AM	Presentation by John Ferritto	
11:00 AM	Presentation by Bob Reithermann	
11:10 AM	Presentation by Keith Porter on NIST/RS Means Organization and Project Occupancies	
11:20 AM	Discussion by all on how we should go about deciding which nonstructural components are significant to performance. What data exists to validate our judgments? How do significant components vary by occupancy?	All
Noon	Lunch	
12:30 PM	Begin Decision Making on Significant Non Structural Components	
2:30 PM	Break	
2:45 PM	Continue Decision Making with variations with Occupancy	
5:00 PM	Summarize and Adjourn by 5:15 PM.	

Invited Workshop Participants

Mike Mahoney/Jeff Lusk – ATC-58 FEMA Project Officer

Bob Hanson - ATC-58 FEMA Technical Representative

Chris Rojahn - ATC Executive Director and ATC-58 Project Technical Director

Jon Heintz - ATC Project Manager for the ATC-58 Project

Ron Hamburger – ATC-58 Project Technical Director

Andrew Whittaker – ATC-58 Project Team Leader for Structural Performance Products

Bob Bachman – ATC-58 Project Team Leader for Non Structural Performance Products

Craig Comartin – ATC-58 Project Team Leader for Risk Management Performance Products

Maryann Phipps – Member of the ATC-58 Project Management Committee

Bill Holmes – Chair of the ATC-58 Project Steering Committee

John Gillengerten – Member of the ATC-58 Project Steering Committee

Eduardo Miranda – Stanford – Member of Nonstructural Team

Keith Porter – Caltech – Member of Nonstructural Team

Mary Comerio – UC Berkeley and Howard Blecher – Research Assistant

Thalia Anangos – San Jose State

Bob Reithermann – Executive Director of CUREE

Gee Hecksher – AIA – Cost Estimation – Member of Risk Management Team

John Eidinger – President, G&E Engineering Systems

Bill Gates – Vice President - URS

John Ferritto – Consultant – Retired from Pt. Hueneme

Sam Swan – Consultant – Formerly with ABS

ATC-58
Development of Next-Generation Performance Based Design Guidelines

Ronald O. Hamburger, SE
Project Technical Director

Principal
Simpson Gumpertz & Heger, Inc.
Consulting Engineers

Project Goals

- Develop next-generation criteria for performance-based design of buildings
- Applicable to:
  - Design of new buildings
  - Upgrade of existing buildings
- Compatible with performance based approaches for other extreme hazards:
  - Fire
  - Blast

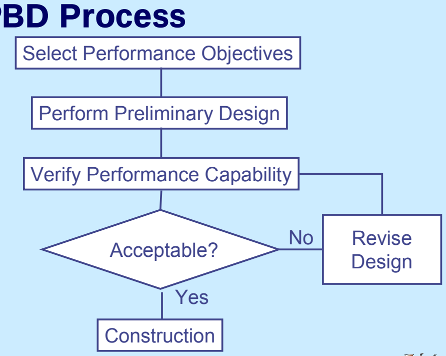
Goals of Performance-based Design

- Permit seismic (fire, blast) protection to be provided at lower cost
- Permit superior protection to be achieved when required
- Permit prescriptive provisions of building codes to be improved without waiting for a disaster

Performance-based Design Development History

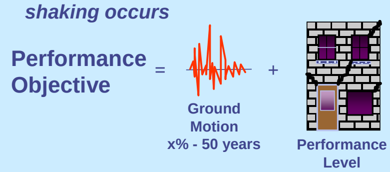
- 1993-1997 FEMA invested in the development of performance-based design guidelines for seismic upgrade
  - ATC-33 project
  - FEMA-273/274- NERHP Guidelines and Commentary for Seismic Rehabilitation of Buildings
  - FEMA-310 Handbook for Seismic Evaluation of Buildings
  - FEMA-356 Prestandard for Seismic Rehabilitation of Buildings
  - ASCE-31 Standard for Seismic Evaluation of Buildings
  - ASCE-41 Standard for Seismic Rehabilitation of Buildings

The PBD Process

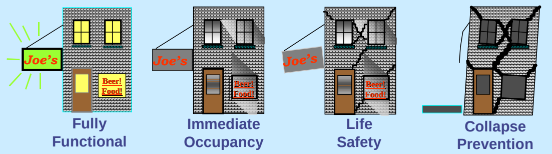


Present Generation Performance Objectives

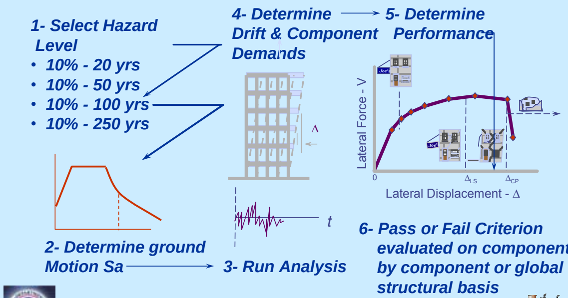
- Specification of :
  - *Design Hazard (earthquake ground shaking)*
  - *Acceptable Performance Level (maximum acceptable damage, given that shaking occurs*



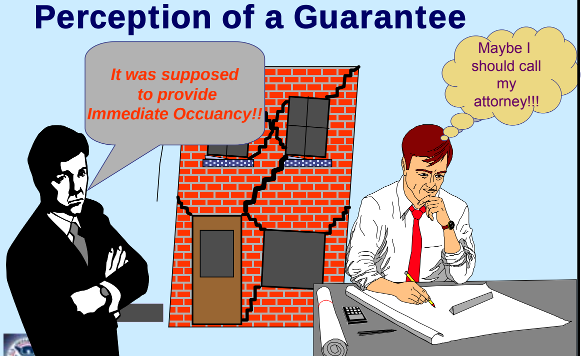
Present Generation Performance Levels



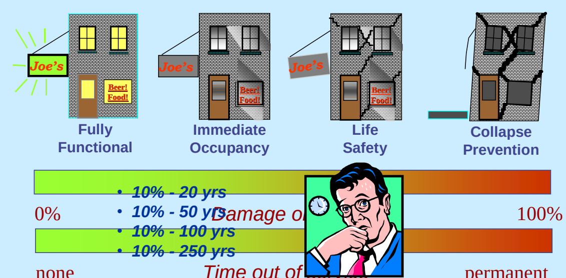
Evaluation Approach



Perception of a Guarantee



Decision Maker Difficulty in Selecting Appropriate Performance



Performance Next-Generation PBD

- The potential consequences of building response to earthquakes, including:
  - Life loss & injuries
  - Direct economic loss (repair and replacement costs)
  - Indirect economic and social loss (loss of use of damaged or destroyed facilities)

Next Generation Performance Assessment

- Adopt methods of loss estimation similar to HAZUS, EQECAT, RMS and other models
- User-friendly, yet sufficiently precise for building-specific assessment
  - Not tied to pushover analysis
  - Multiple levels of assessment
    - Schematic design
    - Detailed design or existing building
  - Permit user to understand principal sources of loss so design decisions can be guided

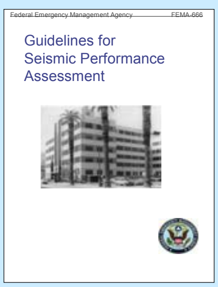
Implementing the Process

- Intent is to keep engineer's task as close as possible to current practice
  - Define building
    - Structure
    - Nonstructural dressing
    - Construction value
    - Occupancy
  - Analyze structure and predict demands
  - Evaluate Potential Losses
- Software will be available to perform loss calculations

ATC-58 Project

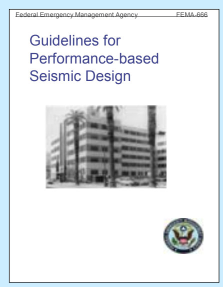
- Initiated in 2002
- ✓ Phase 1
  - Review and Update FEMA-349 Program Plan, Published as FEMA 445
- ✓ Phase 2
  - Determine basic procedures and framework
- ➢ Phase 3
  - Development of Performance Assessment Guidelines
- Phase 4
  - Development of Design Guidance

Project Products



- Guidelines for assessing potential:
  - Repair costs
  - Occupancy interruption
  - Casualties
- Will include software for calculating losses
- Scheduled for release - 2009

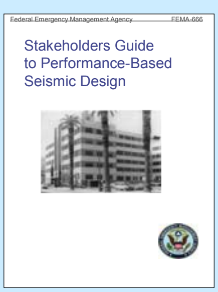
Project Products



- Recommendations on:
  - selection of appropriate systems
  - strength, stiffness, and ductiltiy
  - nonstructural installation

  for various performance objectives
- Scheduled release 2014

Project Products

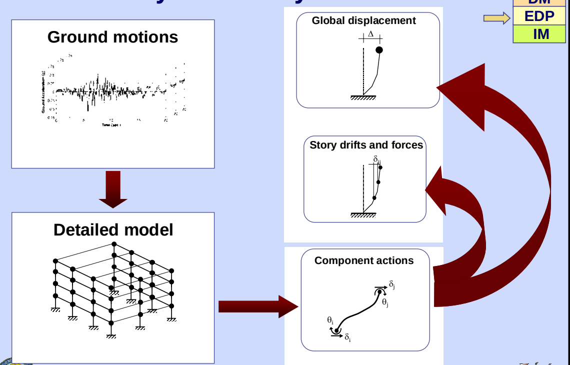


- Recommendations for:
  - building officials
  - building owners
  - lenders
  - tenants
  - insurers

  how to take advantage of this new technology

Nonlinear dynamic analysis

DV DM EDP IM



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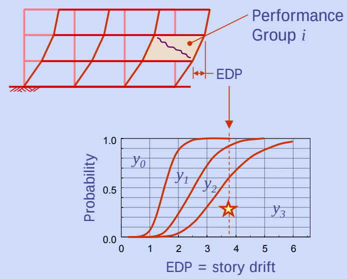
Performance groups

DV DM EDP IM



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Performance group damage states

DV DM EDP IM

Name	Location	EDP	Components	Quantities
SH12	between L1 and L2	$d_{1\text{-}2}$	Steel moment connection	One each side of col

	Damage States		
	DS1	DS2	DS3
Description of damage	Cracking or fracture of weldments	Buckling or fracture of beam flanges and/or webs; minor buckling of column flanges or continuity plates	Fracture of column flanges and/or web

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Performance group damage states

DV DM EDP IM

		Damage States		
Division	Subject	DS1	DS2	DS3
6	Structural steel	Gouge and re-weld	Remove and replace locally	Replace entire joint assembly
8	Doors, windows, etc.	No work	Remove exterior cladding, store and reinstall 20 lineal feet Remove and replace windows 150 sq. feet	Remove exterior cladding, store and reinstall 20 lineal feet Remove and replace windows 150 sq. feet
9.01	Finishes	Remove and replace drywall; repaint 120 sq. feet	Remove and replace drywall; repaint 120 sq. feet	Remove and replace drywall; repaint 120 sq. feet
9.02	Ceilings	Remove and replace tiles and grid 400 sq ft	Remove and replace tiles and grid 400 sq ft	Remove and replace tiles and grid 900 sq ft
16	Mechanical systems	Remove (re-route), store and replace pipes and ducts Duct: 20 lineal feet Pipe: 20 lineal feet	Remove (re-route), store and replace pipes and ducts Duct: 20 lineal feet Pipe: 20 lineal feet	Remove (re-route), store and replace pipes and ducts Duct: 40 lineal feet Pipe: 80 lineal feet

Performance group damage measures

DV DM EDP IM

		REPAIR MEASURE	Units	Performance Group SH12 DS1	DS2	DS3
		STRUCTURAL				
		Demolition/Access				
		Finish protection	sf	6,000	6,000	6,000
		Ceiling system removal	sf	2,000	3,000	5,000
		Drywall assembly removal	sf	800	800	6,000
		Miscellaneous MEP	loc	2	4	6
		Remove exterior skin (salvage)	sf			5,600
		Repair				
x	x	Welding protection	sf	1,500	1,500	1,500
x	x	Shore beams below & remove	loc			12
x	x	Cut floor slab at damaged conn.	sf	70	150	1,600
x	x	Carbon arc out weld	lf	40	50	
x		Remove portion of damaged beam/col	sf		100	
x	x	Replace weld - from above	lf	40	40	
x		Replace beam flange and web - weld	sf			
	x	Remove/replace connection	lb			3,000
x	x	Replace slab	sf	70	70	1,600

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Performance group repair cost functions

DV DM EDP IM

QUANTITY DEPENDENT UNIT COSTS
Using linear interpolation for unit costs for total units between max. and min. unit

		REPAIR MEASURE	Units	Min.Qty.	Max. cost	Max.Qty.	Min. cost	Contingency (+/- %)
		STRUCTURAL						
		Demolition/Access						
		Finish protection	sf	1000	$ 0.30	40000	$ 0.15	
		Ceiling system removal	sf	1000	$ 2.00	10000	$ 1.25	
		Drywall assembly removal	sf	1000	$ 2.50	20000	$ 1.50	
		Miscellaneous MEP	loc	6	$ 200.00	24	$ 150.00	
		Remove exterior skin (salvage)	sf	3000	$ 30.00	10000	$ 25.00	
		Repair						
x	x	Welding protection	sf	1000	$ 1.50	10000	$ 1.00	
x	x	Shore beams below & remove	loc	6	$ 2,100.00	24	$ 1,600.00	
x	x	Cut floor slab at damaged conn.	sf	10	$ 200.00	100	$ 150.00	
x	x	Carbon arc out weld	lf	100	$ 15.00	1000	$ 10.00	
x		Remove portion of damaged beam/col	sf	100	$ 80.00	2000	$ 50.00	
x	x	Replace weld - from above	lf	100	$ 50.00	1000	$ 40.00	
x		Replace beam flange and web - weld	sf	100	$ 140.00	1000	$ 110.00	
	x	Remove/replace connection	lb	2000	$ 6.00	20000	$ 5.00	
x	x	Replace slab	sf	100	$ 20.00	1000	$ 16.00	

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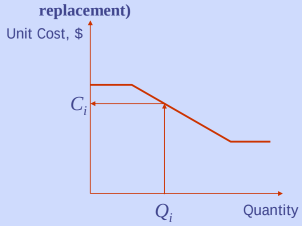
Conceptual repair cost functions

Quantity i (e.g., square feet of wallboard partition replacement)



Total repair cost

Total cost = $\Sigma C_i Q_i$

(plus contractor's OH and profit (~12%) and general project costs (design, admin etc, at 20-50%).

Loss calculation

DV
DM
EDP
IM

Determine damage state for each performance group.

Assemble total repair quantities across all performance groups.

Determine quantity weighted unit cost.

Calculate repair costs for each performance group.

Sum across performance groups for total repair cost.

A PBEE implementation challenge

To conduct a PBEE study on a real building using real earthquake professionals and a realistic budget and timeframe.

Performance groups

Name	Location	EDP	Components
SH12	between levels 1 and 2	d_{1-2}	**Structural lateral:** lateral load resisting system; damage oriented fragility (direct loss calculations)
SH23	between levels 2 and 3	d_{2-3}	
SH3R	between levels 3 and R	d_{3-R}	
EXTD12	between levels 1 and 2	d_{1-2}	**Exterior enclosure:** panels, glass, etc.
EXTD23	between levels 2 and 3	d_{2-3}	
EXTD3R	between levels 3 and R	d_{3-R}	

Performance groups

Name	Location	EDP	Components
INTD12	between levels 1 and 2	d_{1-2}	**Interior nonstructural drift sensitive:** partitions, doors, glazing,etc
INTD23	between levels 2 and 3	d_{1-2}	
INTD3R	between levels 3 and R	d_{3-R}	
INTA2	below level 2	a_1	**Interior nonstructural acceleration sensitive:** ceilings, lights, sprinkler heads, etc
INTA3	below level 3	a_2	
INTAR	below level R	a_3	

Performance groups

Name	Location	EDP	Components
CONT1	at level 1	a_1	**Contents**: General office on first and second floor, computer center on third
CONT2	at level 2	a_2	
CONT3	at level 3	a_3	
EQUIPR	at level R	a_R	**Equipment on roof**

Various expressions of risk

$1.2M

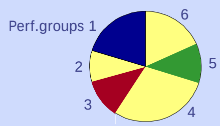
(a) Expected loss for M7 scenario

$2.0M

(b) 90% confidence loss

$50,000

(c) Mean cumulative annual total loss



(d) Contributions to total loss

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Guidelines for Selection of Performance Groups

- **Assemble all "components" (pieces of a building subject to damage) into groups**
  - Note that the direct damage to any component should be represented in only one group. (e.g. interior partitions between the second and third floors). In some instances, indirect damage in one group may be incurred due to direct damage to another group. (e.g. removal of partitions to implement repair to damaged structure).
- **Group components logically with respect to:**
  - Location (floor level)
  - *EDP* (one per group)
  - Fragility (expressed in terms of damage to all components in the assembly)
  - Loss impacts (deaths, dollars, downtime)

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ATC-58 Nonstructural Components

What matters?

Eduardo Miranda

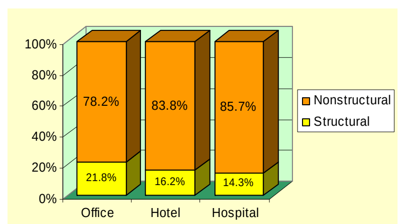
The measuring stick is based decision variables (DV)

1. Economic losses (dollars)
2. Loss of functionality, loss of use (downtime)
3. Serious injuries or fatalities (deaths)

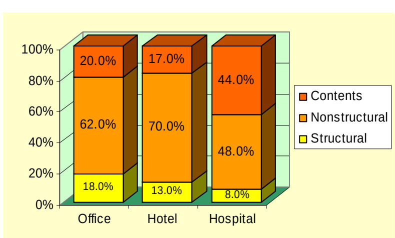
Conditions that make a NSC matter for economic losses

1. Commonly present in the building class being considered
2. Consequences of damage must be relatively expensive
3. Damage is produced at low IM's (relatively high MAF of damage)

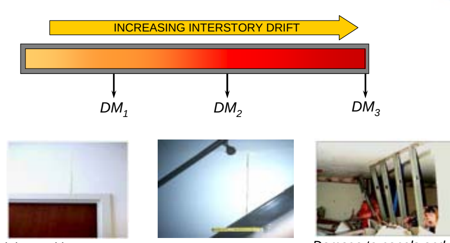
Importance of nonstructural components



Importance of nonstructural components



Example of nonstructural fragility function

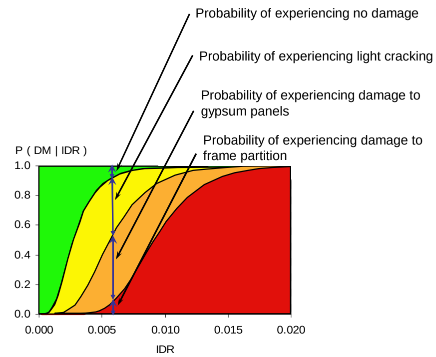


Light cracking

Damage to panels

Damage to panels and frames

Example of use of a nonstructural fragility function



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Conditions that make a NSC matter for downtime

1. ***Commonly present in the building class being considered***
2. ***Consequences of damage must have an important effect on functionality or loss of use***
3. ***Damage is produced at low IM's (relatively high MAF of damage)***

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Conditions that make a NSC matter for injuries/deaths

1. ***Commonly present in the building class being considered***
2. ***Damage must have a significant probability effect of causing severe injuries or fatalities***

   This often means heavy NSCs, but not always (glazing, chemical spills, fire potential, etc.)
3. ***Damage is produced at low IM's (relatively high MAF of damage)***

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DOWNTIME MODELING FOR RISK MANAGEMENT: Comparison of Design Standards and Damage Assessment

Mary Comerio, UC Berkeley
Howard Blecher, UC Berkeley

Downtime in PBEE and Loss Modeling

- Performance Based Earthquake Engineering Decision Variables
  - Deaths
  - Dollars
  - Downtime
- Economic Impacts in Loss Modeling
  - Secondary Impacts, such as:
  - Service Interruption for lifelines, schools
  - Business Interruption
  - Opportunity Costs

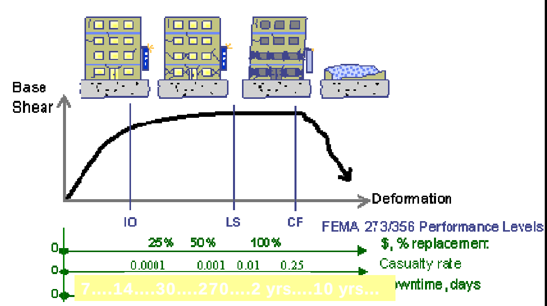


Figure 1 – Schematic of PBEE assessment process and performance metrics

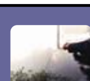
Defining Downtime

- 1. The rational—the time to repair building components damaged and refinish spaces for use.
- 2. The irrational—the time needed for mobilization and tasks and decisions unrelated to the damage specifics. These include:
  - Financing
  - Relocation of Functions (Surge)
  - Management/Manpower
  - Economic and Regulatory Uncertainty

Performance Levels and Damage States

PEER	FEMA 356		Vision 2000			ATC 20	
	Performance Level (Structural/Nonstructural)	*Damage*	*Damage States and Performance Level Thresholds*	*Damage Index*	*Damage Range*	*Posting*	*Tag Color*
	Operational (N-A)	Light	Fully Operational / Functional	10 9	Negligible	Inspected	Green
	Immediate Occupancy (N-B) / Immediate Occupancy (S-1)		Operational	8 7	Light		
	Life Safety (N-C) / Life Safety (S-3)	Moderate	Life Safe	6 5	Moderate	Restricted Use	Yellow
	Hazards Reduced (N-D) / Collapse Prevention (S-5)	Severe	Near Collapse	4 3	Severe		
			Collapse	2 1	Complete	Unsafe / Area Unsafe	Red

Nonstructural Performance Level
Architectural Components



Cladding

PEER	FEMA 356	Vision 2000	ATC 20
	Connections yield; minor cracks (<1/16" width) or bending in cladding.	Negligible Damage.	
	Connections yield; minor cracks (<1/16" width) or bending in cladding.	Connections yield; some cracks or bending in cladding.	
	Severe distortion in connections. Distributed cracking, bending, crushing, and spalling of cladding elements. Some fracturing of cladding, but panels do not fall.	Severe distortion in connections. Distributed cracking, bending, crushing, and spalling of cladding elements. Some fracturing of cladding, falling of panels prevented.	
	Severe distortion in connections. Distributed cracking, bending, crushing, and spalling of cladding elements. Some fracturing of cladding, but panels do not fall in areas of public assembly.	Severe damage to connections and cladding. Some falling of panels.	
			Overall Level of Damage: Possibility of Falling Hazards. Panel Connections: Broken or Damaged Connections. Walls with Some Fallen Panels. (Section 12.2.3: Cladding)

Nonstructural Performance Level
Architectural Components

Glazing


UCSD

UCSD

PEER	FEMA 356	Vision 2000	ATC 20
	Some cracked panes; none broken.	Generally no damage; isolated cracking possible.	
	Some cracked panes; none broken.	Some broken glass; falling hazards avoided.	
	Extensive cracked glass; little broken glass.	Extensive broken glass; same falling hazard.	
	General shattered glass and distorted frames in unoccupied areas. Extensive cracked glass; little broken glass in occupied areas.	General shattered glass and distorted frames; widespread falling hazards.	
			Glazing: Possible Falling Glass. (Section 12.2.5: Interior Walls, Partitions, and Glazing)

Nonstructural Performance Level
Architectural Components

Partitions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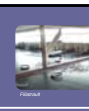
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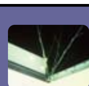
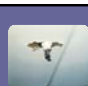
PEER	FEMA 356	Vision 2000	ATC 20
	Cracking to about 1/16" width at openings. Minor crushing and cracking at corners.	Negligible damage; some hairline cracks at openings.	
	Cracking to about 1/16" width at openings. Minor crushing and cracking at corners.	Cracking to about 1/16" width at openings; crushing and cracking at corners.	
	Distributed damage; some severe cracking, crushing, and racking in some areas.	Distributed damage; some severe cracking, crushing, and racking in some areas.	
	Distributed damage; some severe cracking, crushing, and racking in some areas.	Severe racking and damage in many areas.	
			Overall Level of Damage: Collapsed or Partially Collapsed, or Severely Cracked Partitions. Masonry/Tile Partitions: Cracked Masonry or Tile Partitions. Demountable partitions: Separation from Supports (Section 12.2.5: Interior Walls, Partitions, and Glazing)

Nonstructural Performance Level
Architectural Components

Ceilings

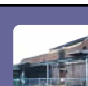

ATC20 Training

ATC20 Training

ATC20 Training

PEER	FEMA 356	Vision 2000	ATC 20
	Generally negligible damage. Isolated suspended panel dislocations, or cracks in hard ceilings.	Generally negligible damage. Isolated suspended panel dislocations, or cracks in hard ceilings.	
	Minor damage. Some suspended ceiling tiles disrupted. A few panels dropped. Minor cracking in hard ceilings.	Minor damage; some suspended ceiling tiles disrupted, panels dropped; minor cracking in hard ceilings.	
	Extensive damage. Dropped suspended ceiling tiles. Moderate cracking in hard ceilings.	Extensive damage; Dropped suspended ceilings. Distributed cracking in hard ceilings.	
	Extensive damage. Dropped suspended ceiling tiles. Moderate cracking in hard ceilings.	Most ceilings damaged; most suspended ceilings dropped, severe cracking in hard ceilings.	
			Overall Level of Damage: Collapse or Partial Collapse. Suspended Acoustical Ceilings: Collapse or Incipient Collapse. Friable Asbestos Release. Plaster and Gypsum Ceilings: Separation or Partial Collapse. (Section 12.2.4: Ceilings and Light Fixtures)

Nonstructural Performance Level
Architectural Components

Parapets & Ornamentation


ATC20 Training

ATC20 Training

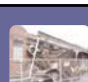
ATC20 Training

PEER	FEMA 356	Vision 2000	ATC 20
	Minor damage.		
	Minor damage.		
	Extensive damage; some falling in unoccupied areas.		Obvious parapet falling hazard present (From Table 4.1, Basic Rapid Evaluation Criteria)
	Extensive damage; some falling in unoccupied areas.		
			Masonry Parapets: Partially Dislodged Parapets. Cracked Parapets (No Evidence of Reinforcement. Concrete Parapets: Major Spalling. Severe Lean. Ornamentation / Cornices / Mansards: Evidence of Support Distress. Partial Dislodgement. Signs: Damaged Supports. Veneer/Roof Tile: Fallen or Damaged Veneer. (Section 12.2.1: Parapets, Ornamentation, and Appendages - Inspection List) Cracked Parapet or Cornice. (Section 7.1: Unreinforced Masonry Construction)

Nonstructural Performance Level
Architectural Components

Canopies & Marquees*


ATC20 Training

ATC20 Training

ATC20 Training

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Minor damage.		
	Minor damage.		
	Moderate damage.		
	Moderate damage.		
			Canopies and Sunscreens: Canopy, Porch or Sunscreen Separation. (Section 6.1: Wood Frame Dwellings and Small Buildings) Overall Level of Damage: Any lean of freestanding canopies indicates potential instability. Failure of Support at Building. (Section 12.2.2: Canopies)

Nonstructural Performance Level
Architectural Components

Chimneys & Stacks*


ATC20 Training

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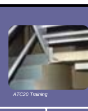
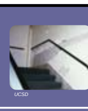
PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Negligible damage.		
	Minor cracking.		
	Extensive damage. No collapse.		Obvious chimney falling hazard present (From Table 4.1, Basic Rapid Evaluation Criteria)
	Extensive damage. No collapse.		
			Chimneys: Chimney Falling Hazard. (Section 6.1: Wood Frame Dwellings and Small Buildings)

Nonstructural Performance Level
Architectural Components

Stairs & Fire Escapes


ATC20 Training


UCSD

PEER	FEMA 356	Vision 2000	ATC 20
	Negligible damage.	Not impaired.	
	Minor damage.	No major obstructions in exit corridors. Elevators can be restarted perhaps following minor servicing.	
	Some racking and cracking of slabs. Usable.	No major obstructions in exit corridors. Elevators may be out of service for an extended period.	
	Extensive racking. Loss of use.	Egress may be obstructed.	
		Egress may be highly or completely obstructed.	Stairs/Exits: All exits are Blocked or Otherwise Unusable. Unsafe Condition at Stairway, Exitway, or Inoperable Exit Door. (Section 12.2.8: Other Hazards)

Nonstructural Performance Level
Architectural Components

Doors


UCSD

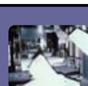

UCSD


UCSD

PEER	FEMA 356	Vision 2000	ATC 20
	Minor damage. Doors operable.	Negligible damage.	
	Minor damage. Doors operable.	Minor damage.	
	Distributed damage. Many racked and jammed doors.	Distributed damage. Some racked and jammed doors.	
	Distributed damage. Many racked and jammed doors.	Distributed damage. Many racked and jammed doors.	
			Stairs/Exits: Inoperable Exit Door. (Section 12.2.8: Other Hazards)

Nonstructural Performance Level
Mechanical, Electrical, and
Plumbing Systems/Components*

Light Fixtures


ATC20 Training


ATC20 Training

PEER	FEMA 356	Vision 2000 (*In "Architectural Elements")	ATC 20
	Negligible damage.	Negligible damage; pendant fixtures sway.	
	Minor damage. Some pendant lights broken.	Minor damage. Some pendant lights broken; falling hazards broken.	
	Many broken light fixtures. Falling hazards generally avoided in heavier fixtures (>20 pounds).	Many broken light fixtures; falling hazards generally avoided in heavier fixtures (>20 lbs +/-).	
	Many broken light fixtures. Falling hazards generally avoided in heavier fixtures (>20 pounds) in areas of public assembly.	Extensive damage; falling hazards occur.	
			Pendant Fluorescent Light Fixtures: Damaged Stems (without Cables). Collapse of Some Fixtures. Other Light Fixtures: Obvious or Possible Falling Hazard. (Section 12.2.4: Ceilings and Light Fixtures)

Nonstructural Performance Level
Mechanical, Electrical, and
Plumbing Systems/Components

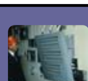
Elevators


ATC20 Training

PEER	FEMA 356	Vision 2000	ATC 20
	Elevators operate.	Elevators operational with isolated exceptions.	
	Elevators operable; can be started when power available.	Elevators generally operational; most can be restarted.	
	Elevators out of service; counterweights do not dislodge.	Some elevators out of service.	
	Elevators out of service; counterweights off rails.	Many elevators out of service.	
			General: Suspected Damage. Seismic Protection Devices: Elevator with Protective Switch Trip. Counterweights: Counterweights Out of Guides. Guide Rails: Damaged Rails. Guide Rails: Broken Brackets. Elevator Machinery: Equipment Anchorage Failure. Elevator Machinery: Cables Out of Sheaves. Doors: Door Damage. (Section 12.2.7: Elevators)

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

HVAC Equipment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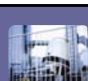
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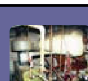
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PEER	FEMA 356	Vision 2000	ATC 20
	Units are secure and operate. Emergency power and other utilities provided, if required.	Negligible Damage all remain in service.	
	Units are secure and most operate if power and other required utilities are available.	Minor damage. Some units, not essential to function out-of-service.	
	Units shift on supports, rupturing attached ducting, piping, and conduit, but do not fall.	Many units non-operational; some slide or overturn.	
	Most units do not operate; many slide or overturn; some suspended units fall.	Most units non-operational; many slide or overturn; some pendant units fall.	
			Gas- and Fuel Oil-Fired Equipment: Overturning or Sliding of Equipment. Gas or Fuel Line Break or Leak. Broken Exhaust Pipe. Other Mechanical and Electrical Equipment: Falling Hazard Present. (Section 12.2.6: Mechanical and Electrical

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Manufacturing Equipment*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Units secure and operable; power and utilities available.		
	Units secure, and most operable if power and utilities available.		
	Units slide, but do not overturn; utilities not available; some realignment required to operate.		
	Units slide and overturn; utilities disconnected. Heavy units require reconnection and realignment. Sensitive equipment may not be functional.		

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Ducts

PEER	FEMA 356	Vision 2000	ATC 20
	Negligible damage.	Negligible damage.	
	Minor damage at joints, but ducts remain serviceable.	Minor damage, but systems remain in service.	
	Ducts break loose of equipment and louvers; some supports fail; some ducts fall.	Some ducts rupture; some supports fail but ducts do not fall.	Overhead Piping and Ducts: Occasional Failed Supports. (Section 12.2.6: Mechanical and Electrical Equipment)
	Ducts break loose of equipment and louvers; some supports fail; some ducts fall.	Most systems out of commission; some ducts fall.	
			Overhead Piping and Ducts: Many Failed Supports. (Section 12.2.6: Mechanical and Electrical Equipment)

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components


ATC20 Training

Piping

PEER	FEMA 356	Vision 2000	ATC 20
	Negligible damage.	Negligible damage.	
	Minor leaks develop at a few joints.	Minor damage. Minor leaking may occur.	
	Minor damage at joints, with some leakage. Some supports damaged, but systems remain suspended.	Some pipes rupture at connections; many supports fail; few fire sprinkler heads fail.	Overhead Piping and Ducts: Occasional Failed Supports. (Section 12.2.6: Mechanical and Electrical Equipment)
	Some lines rupture. Some supports fail. Some piping falls.	Many pipes rupture at connections; supports fail; some piping systems collapse.	
			Overhead Piping and Ducts: Many Failed Supports. (Section 12.2.6: Mechanical and Electrical Equipment)

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Fire Sprinkler Systems*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Negligible damage.		
	Minor leakage at a few heads or pipe joints. System remains operable.		
	Some sprinkler heads damaged by swaying ceilings. Leaks develop at some couplings.		
	Some sprinkler heads damaged by collapsing ceilings. Leaks develop at couplings. Some branch lines fail.		
			Fire Protection/Detection Equipment: Fire Protection / Detection Equipment Inoperable (Section 12.2.8: Other Hazards)

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Fire Alarm Systems

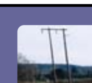
PEER	FEMA 356	Vision 2000	ATC 20
	System is functional.	Functional.	
	System is functional.	Functional.	
	Ceiling mounted sensors damaged. May not function.	Not functional.	
	Ceiling mounted sensors damaged. May not function.	Not functional.	
			Fire Protection/Detection Equipment: Fire Protection / Detection Equipment Inoperable (Section 12.2.8: Other Hazards)

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Emergency Lighting

PEER	FEMA 356	Vision 2000	ATC 20
	System is functional.	Functional.	
	System is functional.	Functional.	
	Some lights fall. Power may be available from emergency generator.	Functional.	
	Some lights fall. Power may not be available.	Not functional.	

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components


UCSD

Electrical Distribution Equipment

PEER	FEMA 356	Vision 2000	ATC 20
	Units are functional. Emergency power is provided, as needed.	Negligible damage.	
	Units are secure and generally operable. Emergency generators start, but may not be adequate to service all power requirements.	Minor damage; panels restrained, isolated loss of function in secondary systems.	
	Units shift on supports and may not operate. Generators provided for emergency power start; utility service lost.	Moderate damage; panels restrained from overturning; some loss of function and service in primary systems.	
	Units slide and/or overturn, rupturing attached conduit. Uninterruptible Power Source systems fail. Diesel generators do not start.	Extensive damage and loss of service.	
			Fallen Electric Lines: Fallen Electric Lines (Section 12.2.8: Other Hazards)

Attachment E

Nonstructural Performance Level
Mechanical, Electrical, and Plumbing
Systems/Components

Plumbing*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	System is functional. On-site water supply provided, if required.		
	Fixtures and lines serviceable; however, utility service may not be available.		
	Some fixtures broken; lines broken; mains disrupted at source.		
	Some fixtures broken; lines broken; mains disrupted at source.		

Nonstructural Performance Level
Contents

Computer Systems

PEER	FEMA 356	Vision 2000	ATC 20
	Units undamaged and operable; power available.	Operational.	
	Units secure and remain connected. Power may not be available to operate, and minor internal damage may occur.	Minor damage; some sliding and overturning. Mostly functional.	
	Units shift and may disconnect cables, but do not overturn. Power not available.	Extensive damage from sliding, overturning, leaks, falling debris, etc.	
	Units roll and overturn, disconnect cables. Raised access floors collapse. Power not available.	Extensive damage from sliding, overturning, leaks, falling debris, etc.	

Nonstructural Performance Level
Contents

Desktop Equipment*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Equipment secured to desks and operable.		
	Some equipment slides off desks.		
	Some equipment slides off desks.		
	Some equipment slides off desks.		

Nonstructural Performance Level
Contents

File Cabinets

PEER	FEMA 356	Vision 2000	ATC 20
	Drawers slide open, but cabinets do not tip.	Negligible damage.	
	Drawers slide open, but cabinets do not tip.	Minor damage; some sliding and overturning.	
	Cabinets overturn and spill contents.	Extensive damage from sliding, overturning, leaks, falling debris, etc.	
	Cabinets overturn and spill contents.	Extensive damage from sliding, overturning, leaks, falling debris, etc.	

Nonstructural Performance Level
Contents

Book Shelves

PEER	FEMA 356	Vision 2000	ATC 20
	Books remain on shelves.	Negligible damage.	
	Books slide on shelves.	Minor damage; some overturning and spilling.	
	Books slide off shelves.	Extensive damage from leaks, falling debris, overturning etc.	
	Shelves overturn and spill contents.	Extensive damage from leaks, falling debris, overturning etc.	

Nonstructural Performance Level
Contents

Hazardous Materials

PEER	FEMA 356	Vision 2000	ATC 20
	Negligible damage; materials contained.	Negligible damage; overturning and spillage restrained.	
	Negligible damage; materials contained.	Negligible damage; overturning and spillage restrained.	
	Minor damage; occasional materials spilled; gaseous materials contained.	Negligible damage; overturning and spillage generally restrained.	
	Minor damage; occasional materials spilled; gaseous materials contained.	Severe damage; some hazardous materials released.	
			Other Hazards: Gas Leak. (Section 6.1: Wood Frame Dwellings and Small Buildings) Chemical / Flammable Material Areas: Spill of Known or Suspected Dangerous Materials. Storage Tanks, Vessels, and Piping: Leakage of Unknown

Nonstructural Performance Level
Contents

Art Objects*

PEER	FEMA 356	Vision 2000 (*In "Art works, collections")	ATC 20
	Objects undamaged.	Minor damage; overturning restrained.	
	Some objects may be damaged by falling.	Moderate damage; overturning restrained; some spilling.	
	Objects damaged by falling, water, dust.	Extensive damage from leaks, falling debris, overturning, spilling etc.	
	Objects damaged by falling, water, dust.	Extensive damage from leaks, falling debris, overturning, spilling etc.	

Nonstructural Performance Level
Contents

Furniture*

PEER	FEMA 356 (*not a FEMA 356 system)	Vision 2000	ATC 20
		Negligible damage.	
		Minor damage; some sliding and overturning.	
		Extensive damage from sliding, overturning, leaks, falling debris, etc.	
		Extensive damage from sliding, overturning, leaks, falling debris, etc.	

Nonstructural Performance Level
Contents

Office equipment*

PEER	FEMA 356 (*not a FEMA 356 system)	Vision 2000	ATC 20
		Negligible damage.	
		Minor damage; some sliding and overturning.	
		Extensive damage from sliding, overturning, leaks, falling debris, etc.	
		Extensive damage from sliding, overturning, leaks, falling debris, etc.	

Nonstructural Performance Level
Contents

Storage racks & cabinets*

PEER	FEMA 356 (*not a FEMA 356 system)	Vision 2000	ATC 20
		Negligible damage; overturning restrained.	
		Moderate damage; overturning restrained; some spilling.	
		Extensive damage from leaks, falling debris, overturning, spilling etc.	
		Extensive damage from leaks, falling debris, overturning, spilling etc.	

Structural Performance Level
Vertical Element

Concrete Frames

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor hairline cracking. Limited yielding possible at a few locations. No crushing (strains below 0.003). Secondary Component: Minor spalling in a few places in ductile columns and beams. Flexural cracking in beams and columns. Shear cracking in joints < 1/16" width. Drift: 1% transient; negligible permanent.	Primary Component: Minor hairline cracking (0.02"); limited yielding possible at a few locations; no crushing (strains below 0.003). Secondary Component: Same as primary.	
	Primary Component: Extensive damage to beams. Spalling of cover and shear cracking (< 1/8" width) for ductile columns. Minor spalling in nonductile columns. Joint cracks <1/8" wide. Secondary Component: Extensive cracking and hinge formation in ductile elements. Limited cracking and/or splice failure in some nonductile columns. Severe damage in short columns. Drift: 2% transient; 1% permanent.	Primary Component: Extensive damage to beams; Spalling of cover and shear cracking (<1/8") for ductile columns. Minor spalling in non-ductile columns. Joints cracked < 1/8" width.. Secondary Component:	
	Primary Component: Extensive Cracking and hinge formation in ductile elements. Limited cracking and/or splice failure in some nonductile columns. Severe damage in short columns. Secondary Component: Extensive spalling in columns (limited shortening) and beams. Severe joint damage. Some reinforcing buckled. Drift: 4% transient or permanent.	Primary Component: Extensive cracking and hinge formation in ductile elements. Limited cracking and/or splice failure in some non-ductile columns Severe damage in short columns. Secondary Component: Extensive spalling in columns (possible shortening) and beams. Severe joint damage. Some reinforcing buckled.	
			Columns: Columns Noticeably Out of Plumb. Buckled or Failed Columns. (Section 8.1: Tilt-up Structures) Slabs and Beams: Separation from Vertical Support. Other Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. Flat Slab Construction: Slab with Punching Shear Cracking or Failure at Columns. Columns: Buckled or Fractured Columns. Massive Spalling and Exposure of Vertical

Structural Performance Level
Vertical Element

Steel Moment Frames

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor local yielding at a few places. No fractures. Minor buckling or observable permanent distortion of members. Secondary Component: Same as primary. Drift: 0.7% transient; negligible permanent.	Primary Component: Minor local yielding at a few places. No fractures. Minor buckling or observable permanent distortion of members.. Secondary Component: Same as primary.	
	Primary Component: Hinges form. Local buckling of some beam elements. Severe joint distortion; isolated moment connection fractures, but shear connections remain intact. A few elements may experience partial fracture. Secondary Component: Extensive distortion of beams and column panels. Many fractures at moment connection, but shear connections remain intact. Drift: 2.5% transient; 1% permanent.	Primary Component: Hinges form; Local buckling of some beam elements. Severe joint distortion. Isolated moment connection fractures. A few elements may experience fracture. Secondary Component: Extensive distortion of beams and column panels. Many fractures at connections.	
	Primary Component: Extensive distortion of beams and column panels. Many fractures at moment connections, but shear connections remain intact. Secondary Component: Same as primary. Drift: 5% transient or permanent.	Primary Component: Extensive distortion of beams and column panels. Many fractures at connections. Secondary Component: Extensive distortion of beams and column panels. Many fractures at connections.	
			Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Moment Frames: Broken, Leaning or Seriously Degraded Moment Frames. Weld or Other Connection Failure at Moment Joint. Flange Buckling near Joints. Noticeable Residual Drift in any Story. (Section 10.2: Moment-Resisting Steel Frames) Overall Damage: Collapse or Partial Collapse. Walls or Columns Noticeably Leaning. (Section 10.5: Steel Frame with Cast-in-Place Concrete or

Structural Performance Level
Vertical Element

Braced Steel Frames

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor yielding or buckling of braces. Secondary Component: Same as primary. Drift: 0.5% transient; negligible permanent	Primary Component: Minor yielding or buckling of braces. No out-of-plane distortions. Secondary Component: Same as primary.	
	Primary Component: Many braces yield or buckle but do not totally fail. Many connections may fail. Secondary Component: Same as primary. Drift: 1.5% transient; 0.5% permanent.	Primary Component: Many braces yield or buckle but do not totally fail. Many connections may fail. Secondary Component: Same as primary.	
	Primary Component: Extensive yielding and buckling of braces. May braces and their connections may fail. Secondary Component: Same as primary. Drift: 2% transient or permanent.	Primary Component: Extensive yielding and buckling of braces. May braces and their connections may fail. Secondary Component: Same as primary.	
			Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Roof and Floor Framing: Broken or Buckled Member in Truss. Failed Connection in Truss. Roof or Floor Framing Separation from Vertical Support. Other Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. Columns: Shear Failure at Base. Columns out of Plumb. Buckled or Bowed Columns. Vertical Bracing: Broken Brace or Connection. Buckled or Greatly Stretched Brace. Horizontal Bracing: Broken Brace or Connection.

Structural Performance Level
Vertical Element

Concrete Walls*

PEER	FEMA 356	Vision 2000 (*In "Concrete shear walls")	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor hairline cracking of walls, <1/16" wide. Coupling beams experience cracking <1/8" width. Secondary Component: Minor hairline cracking of walls, Some evidence of sliding at construction joints. Coupling beams experience cracks <1/8" width. Minor spalling. Drift: 0.5% transient; negligible permanent.	Primary Component: Minor hairline cracking of walls (.02"). Coupling beams experience cracking <1/8" width. Secondary Component: Minor hairline cracking of walls, Some evidence of sliding at construction joints. Coupling beams experience cracks <1/8" width. Minor spalling.	
	Primary Component: Some boundary element stress, including limited buckling of reinforcement. Some sliding at joints. Damage around openings. Some crushing and flexural cracking. Coupling beams: extensive shear and flexural cracks; some crushing but concrete generally remains in place. Secondary Component: Major flexural and shear cracks. Sliding at joints. Extensive crushing. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated. Drift: 1% transient; 0.5% permanent.	Primary Component: Some boundary element stress, including limited buckling of reinforcement. Some sliding at joints. Damage around openings. Some crushing and flexural cracking. Coupling beams: extensive shear and flexural cracks; some crushing but concrete generally remains in place. Secondary Component: Major flexural and shear cracks. Sliding at joints. Extensive crushing. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated.	Solid Shear Walls: Diagonal (Shear) Cracks of 1/8 Inch Wide or More Extending Between Floors. (Section 9.2: Cast-in-Place Concrete Building)
	Primary Component: Major flexural and shear cracks and voids. Sliding at joints. Extensive crushing and buckling of reinforcement. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated Secondary Component: Panels shattered and virtually disintegrated Drift: 2% transient or permanent	Primary Component: Major flexural and shear cracks and voids. Sliding at joints. Extensive crushing and buckling of reinforcement. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated. Secondary Component: Panels shattered and virtually disintegrated.	
			Overall Damage: Collapse or Partial Collapse. Building Noticeably Leaning. Wall Panels: Outward Leaning Wall Panel. Broken or Severely Damaged Closure Strips, or A Number of Broken Tie Plates. Wall Instability Resulting from Cracking of Panels. Wall, Corbel or Pilaster Cracking That Jeopardizes Vertical Support of Beam or Truss. (Section 8.1: Tilt-up Structures)

Structural Performance Level
Vertical Element

Unreinforced Masonry Infill Walls

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor (<1/8" width) cracking of veneers. Minor spalling in veneers at a few corner openings. Secondary Component: Same as primary. Drift: 0.1% transient; negligible permanent	Primary Component: Minor (<1/8" width) cracking of veneers. Minor spalling in veneers at a few corner openings. Secondary Component: Same as primary.	
	Primary Component: Extensive cracking and some crushing but wall remains in place. No falling units. Extensive crushing and spalling of veneers at corners of openings. Secondary Component: Same as primary. Drift: 0.5% transient; 0.3% permanent	Primary Component: Extensive cracking and some crushing but wall remains in place. No falling units. Extensive crushing and spalling of veneers at corners of openings. Secondary Component: Same as primary.	
	Primary Component: Extensive cracking and crushing; portions of face course shed. Secondary Component: Extensive crushing and shattering; some walls dislodge Drift: 0.6% transient or permanent	Primary Component: Extensive cracking and crushing; portions of face course shed. Secondary Component: Extensive cracking and crushing; portions of face course shed.	
			Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Roof or Floor Separation from Wall. Pilaster Cracking. Other Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. Columns Noticeably Out of Plumb. Buckled or Failed Columns. Walls out of Plumb. Diagonal or Other Large Cracking. Wythe Separation and Masonry Spalling. Cracking that Jeopardizes Vertical Support. Veneer Separation. (Section 7.1: Unreinforced Masonry Construction)

Structural Performance Level
Vertical Element

Unreinforced Masonry (Noninfill) Walls*

PEER	FEMA 356	Vision 2000 (*In "URM Bearing walls")	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor (<1/8" width) cracking of veneers. Minor spalling in veneers at a few corner openings. No observable out-of-plane offsets. Secondary Component: Same as primary. Drift: 0.3% transient; 0.3% permanent	Primary Component: Minor cracking (<1/8" width) masonry infills and veneers. Minor spalling in veneers at a few corner openings. No observable out-of-plane offsets. Secondary Component: Same as primary.	
	Primary Component: Extensive cracking. Noticeable in-plane offsets of masonry and minor out-of-plane offsets. Secondary Component: Same as primary. Drift: 0.6% transient; 0.6% permanent	Primary Component: Extensive cracking. Noticeable in-plane offsets of masonry and minor out-of-plane offsets. Secondary Component: Same as primary.	
	Primary Component: Extensive cracking; face course and veneer may peel off. Noticeable in-plane and out-of-plane offsets. Secondary Component: Nonbearing panels dislodge. Drift: 1% transient or permanent	Primary Component: Extensive cracking; face course and veneer may peel off. Noticeable in-plane and out-of-plane offsets. Secondary Component: Same as primary.	
			Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Roof and Floor Framing: Roof or Floor Separation from Wall. Pilaster Cracking. Other Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. Columns: Columns Noticeably Out of Plumb. Buckled or Failed Columns. Unreinforced Masonry Walls: Walls out of Plumb. Diagonal or Other Large Cracking. Wythe Separation and Masonry Spalling. Cracking that Jeopardizes Vertical Support. Adobe Construction: Adobe Building

Structural Performance Level
Vertical Element

Reinforced Masonry Walls

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Minor (<1/8" width) cracking. No out-of-plane offsets. Secondary Component: Same as primary. Drift: 0.2% transient; 0.2% permanent	Primary Component: Minor (<1/8" width) cracking. No out-of-plane offsets. Secondary Component: Same as primary.	
	Primary Component: Extensive cracking. (<1/4") distributed throughout wall. Some isolated crushing. Secondary Component: Crushing; extensive cracking. Damage around openings and at corners. Some fallen units. Drift: 0.6% transient; 0.6% permanent	Primary Component: Extensive cracking. (<1/4") distributed throughout wall. Some isolated crushing. Secondary Component: Crushing; extensive cracking. Damage around openings and at corners. Some fallen units.	Reinforced Masonry Walls: Walls with 1/8 Inch or Larger Diagonal (Shear) Cracks. (Section 7.2: Reinforced Masonry Construction)
	Primary Component: Crushing; extensive cracking. Damage around openings and at corners. Some fallen units. Secondary Component: Panels shattered and virtually disintegrated. Drift: 1.5% transient or permanent	Primary Component: Crushing; extensive cracking. Damage around openings and at corners. Some fallen units. Secondary Component: Panels shattered and virtually disintegrated.	
			Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Roof and Floor Framing: Roof or Floor Separation from Wall. Pilaster Cracking. Other Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. Reinforced Masonry Walls: Walls with 1/8 Inch or Larger Diagonal (Shear) Cracks. Several Failed Piers at Any One Story Level. Walls with Out-of-Plane Leaning. Wall or Pilaster Cracking or Spalling the Jeopardizes Vertical Support. Horizontal Diaphragms: Bowed Broken or

Structural Performance Level
Vertical Element

Wood Stud Walls

PEER	FEMA 356	Vision 2000	ATC 20
		Primary Component: Negligible. Secondary Component: Negligible.	
	Primary Component: Distributed minor hairline cracking of gypsum and plaster veneers. Secondary Component: Same as primary. Drift: 1% transient; 0.25% permanent	Primary Component: Distributed minor hairline cracking of gypsum and plaster veneers. Secondary Component: Same as primary.	
	Primary Component: Moderate loosening of connections and minor splitting of members. Secondary Component: Connections loose. Nails partially withdrawn. Some splitting of members and panels. Drift: 2% transient; 1% permanent	Primary Component: Moderate loosening of connections and minor splitting of members. Secondary Component: Connections loose. Nails partially withdrawn. Some splitting of members and panels.	
	Primary Component: Connections loose. Nails partially withdrawn. Some splitting of members and panels. Veneers dislodged. Secondary Component: Sheathing sheared off. Let-in braces fractured and buckled. Framing split and fractured Drift: 3% transient or permanent	Primary Component: Connections loose. Nails partially withdrawn. Some splitting of members and panels. Veneers dislodged. Secondary Component: Sheathing sheared off. Let-in braces fractured and buckled. Framing split and fractured.	
			Overall Damage: Collapse or Partial Collapse. Separation Between Two Parts of a Building. Walls: Residual Racking of 1 to 2 Inches or More Per Story. Cripple Wall Failure. Posts with Residual Lean. Broken Bracing. Post or Pier Displacement. Other Hazards: Veneer Falling Hazard. Tile Roof Falling Hazard. Other Falling Hazard Present. (Section 6.1: Wood Frame Dwellings and Small Buildings) Overall Damage: Collapse or Partial Collapse. Building or Individual Story Noticeably Leaning. Columns Noticeably Out of Plumb. Buckled or

Structural Performance Level
Vertical Element

Precast Concrete Connections*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Primary Component: Minor working at connections; cracks <1/16" width at connections. Secondary Component: Minor crushing and spalling at connections. Drift: N/A		
	Primary Component: Local crushing and spalling at connections, but no gross failure of connections. Secondary Component: Some connection failures but no elements dislodged. Drift: N/A		
	Primary Component: Some connection failures but no elements dislodged. Secondary Component: Same as primary. Drift: N/A		
			Beam-Column and Other Primary Member Connections: Failed Joints of Primary Members. Corbel or Other Cracking that Threatens Vertical Support. Massive Spalled Concrete in Closure Strip. (Section 9.3: Precast Element Structures) Slab-Column Joint: Punching Shear Cracking or Failure in Slab. Failure in Slab-Column Load Transfer Connection. Slippage of 1/8 Inch or More at Slab-Wall Joint. (Section 9.4: Liftslab Structures)

Structural Performance Level
Vertical Element

Foundations

PEER	FEMA 356	Vision 2000	ATC 20
		Negligible.	
	Minor settlement and negligible tilting.	Minor settlement and negligible tilting.	
	Total settlements <6" and differential settlements <1/2" in 30 ft.	Total settlements <6" and differential settlements <1/2" in 30 ft.	Foundation Anchorage: Signs of Movement. (Section 6.1: Wood Frame Dwellings and Small Buildings) Foundations: Building Showing Signs of Beginning to Move Off Its Foundation. (Section 6.2: Commercial, Institutional, and Industrial Structures)
	Major settlement and tilting.	Major settlement and tilting.	
			Foundation Anchorage: House off Foundation. Fractured Foundations. (Section 6.1: Wood Frame Dwellings and Small Buildings) Foundations: Building Off Its Foundation. Fractured Foundations. (Section 6.2: Commercial, Institutional, and Industrial Structures) Fractured Foundations. (Section 7.1: Unreinforced Masonry Construction) Foundations: Fractured Foundations. (Section 7.2: Reinforced Masonry Construction) Foundations: Fractured Foundations. (Section

Structural Performance Level
Horizontal Element

Metal Deck Diaphragms

PEER	FEMA 356	Vision 2000	ATC 20
		Negligible.	
	Connections between deck units and framing intact. Minor distortions.	Connections between deck units and framing intact. Minor distortions.	
	Some localized failure of welded connections of deck to framing and between panels. Minor local buckling of deck.	Some localized failure of welded connections of deck to framing and between panels. Minor local buckling of deck.	
	Large distortion with buckling of some units and tearing of many welds and seam attachments.	Large distortion with buckling of some units and tearing of many welds and seam attachments.	
			Horizontal Diaphragms: Bowed, Broken or Seriously Damaged Diaphragm. Broken or Severely Damaged Chord or Collector. Movement or Failure at Shear Connection between Diaphragm and Beam. Horizontal Cracks 1/2 Inch Wide or Larger in Concrete Structural Slabs. (Section 10.1: Braced Steel Frames)

Structural Performance Level
Horizontal Element

Wood Diaphragms

PEER	FEMA 356	Vision 2000	ATC 20
		Negligible.	
	No observable loosening or withdrawal of fasteners. No splitting of sheathing or framing.	No observable loosening or withdrawal of fasteners. No splitting of sheathing or framing.	
	Some splitting at connections. Loosening of sheathing. Observable withdrawal of fasteners. Splitting of framing and sheathing.	Some splitting at connections. Loosening of sheathing. Observable withdrawal of fasteners. Splitting of framing and sheathing.	
	Large permanent distortion with partial withdrawal of nails and extensive splitting of elements.	Large permanent distortion with partial withdrawal of nails and extensive splitting of elements.	
			Roof and Floor Framing: Roof or Floor Displaced from Walls. Failure or Incipient Failure of Significant Vertical Load-Carrying Element or Connection. (Section 6.1: Wood Frame Dwellings and Small Buildings) Roof Trusses, Heavy Framing: Failed Member or Connection in Roof Truss. Roof Truss or Heavy Framing Separation from Vertical Support. Other Failure or Incipient Failure of significant Vertical Load-Carrying Element or Connection. Roof/Floor Framing has Pulled Away from Vertical Support. Bowed, Broken or Seriously

Structural Performance Level
Horizontal Element

Concrete Diaphragms

PEER	FEMA 356	Vision 2000	ATC 20
		Negligible.	
	Distributed hairline cracking. Some minor cracks of larger size (<1/8" width).	Distributed hairline cracking. (<1/8") of larger size. Some minor cracks of larger size (<1/8" width).	
	Extensive cracking (<1/4" width). Local crushing and spalling.	Extensive cracking (<1/4" width). Local crushing and spalling.	
	Extensive crushing and observable offset across many cracks.	Extensive crushing and observable offset across many cracks.	
			Horizontal Diaphragms: Bowed Broken or Seriously Damaged Diaphragm. Movement or Failure at Shear Connection Between Diaphragm and Masonry Wall. (Section 7.1: Unreinforced Masonry Construction) Horizontal Diaphragms: Bowed Broken or Seriously Damaged Diaphragm. Broken Chord or Collector. Movement or Failure at Shear Connection between Diaphragm and Masonry Wall. (Section 7.2: Reinforced Masonry Construction) Roof and Floor Framing: Failed Member or

Structural Performance Level
Horizontal Element

Precast Diaphragms*

PEER	FEMA 356	Vision 2000 (*not a Vision 2000 system)	ATC 20
	Some minor cracking along joints.		
	Extensive cracking (<1/4" width). Local crushing and spalling.		
	Connections between units fail. Units shift relative to each other. Crushing and spalling at joints.		

Structural Performance Level

Prefabricated Metal* **

PEER	FEMA 356 (*not a FEMA 356 system)	Vision 2000 (**not a Vision 2000 system)	ATC 20
			Overall Damage: Collapse or Partial Collapse. Residual Story Drift of 2 Inches or More (in 10 Feet). Wall Bracing: Rod Connection Failure. Broken Rods or Greatly Stretched Rods. Roof Bracing: Rod or Connection Failure. Severe Racking of Decking. Steel Bents: Buckled Flange in Bent. Failed Bolted Moment Connection. Base Plate with Sheared Anchor Bolts. Frame Out of Plumb 1 to 2 Inches or More. (Section 10.3: Prefabricated Metal Buildings)

Structural Performance Level

Geotechnical Hazards* **

PEER	FEMA 356 (*not a FEMA 356 system)	Vision 2000 (**not a Vision 2000 system)	ATC 20
			Surface Fault Rupture: Building Damaged by Fault Rupture. Slope Failures: Slope Failure Has Caused Foundation Damage or Loss of Foundation Support. Building in Active Slope Failure Zone. Building in Past of Debris, Including Rock Fall, from Active Slope failure Zone. Other Differential Ground Movements: Building Damaged by Ground Displacement. Ground Fissures and Scarps More Than 4" Wide Near Buildings. Slope Failures: Slope Movement Continuing Under Static Conditions. (Section 11.3: Geotechnical Hazards)

Nonstructural Performance Level

Top 3 Most Detailed Damage Conditions by Damage State (Descending level of detail)

PEER	FEMA 356	Vision 2000	ATC 20
	•Ceilings •Partitions •HVAC Equipment	•Ceilings •Partitions •Hazardous Materials	
	•Electrical Distribution Equipment •Ceilings •Partitions	•Electrical Distribution Equipment •Ceilings •Stairs & Fire Escapes	
	•Cladding •Electrical Distribution Equipment •Manufacturing Equipment	•Cladding •Electrical Distribution Equipment •Light Fixtures	•Parapets & Ornamentation* •Chimneys & Stacks* •Ducts** •Piping**
	•Cladding •Manufacturing Equipment •Electrical Distribution Equipment	•Ceilings •Piping •Glazing	* Same level of detail ** Same level of detail
			•Parapets & Ornamentation •Elevators •Hazardous Materials

Structural Performance Level

Top 3 Most Detailed Damage Conditions by Damage State (Descending level of detail)

PEER	FEMA 356	Vision 2000	ATC 20
		N/A—almost all systems described as "Negligible"	
	•Concrete Frames •Concrete Walls •Unreinforced Masonry (Noninfill) Walls	•Concrete Walls •Unreinforced Masonry (Noninfill) Walls •Steel Moment Frames	
	•Concrete Walls •Concrete Frames •Steel Moment Frames	•Concrete Walls •Steel Moment Frames •Reinforced Masonry Walls	•Foundations Concrete Walls •Reinforced Masonry Walls
	•Concrete Walls •Concrete Frames •Wood Stud Walls	•Concrete Walls •Concrete Frames •Wood Stud Walls	
			•Reinforced Masonry Walls •Foundations •Concrete Diaphragms

Literature References

Nonstructural Performance Levels

System	FEMA 356 System Name	Reference	VISION 2000 System Name	Reference	ATC20 Reference
Cladding	Cladding	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Cladding	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.3: Cladding
Glazing	Glazing	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Glazing	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.5: Interior Walls, Partitions, and Glazing
Partitions	Partitions	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Partitions	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.5: Interior Walls, Partitions, and Glazing
Ceilings	Ceilings	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Ceilings	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.4: Ceilings and Light Fixtures
Parapets & Ornamentation	Parapets & Ornamentation	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	N/A	N/A	From Table 4.1, Basic Rapid Evaluation Criteria;; Section 7.1: Unreinforced Masonry Construction; Section 12.2.1: Parapets, Ornamentation, and Appendages - Inspection List
Canopies & Marquees	Canopies & Marquees	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	N/A	N/A	Section 6.1: Wood Frame Dwellings and Small Buildings; Section 12.2.2: Canopies;
Chimneys & Stacks	Chimneys & Stacks	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	N/A	N/A	From Table 4.1, Basic Rapid Evaluation Criteria; Section 6.1: Wood Frame Dwellings and Small Buildings
Stairs & Fire Escapes	Stairs & Fire Escapes	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Egress systems	Table 2-6a and 2-6b: General Damage Descriptions by Performance Levels and Systems	Section 12.2.8: Other Hazards
Doors	Doors	Table C1-5: Nonstructural Performance Levels and Damage--Architectural Components	Doors	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.8: Other Hazards

Literature References

Nonstructural Performance Levels—*con't*

System	FEMA 356 System Name	Reference	VISION 2000 System Name	Reference	ATC20 Reference
Elevators	Elevators	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Elevators	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.7: Elevators
HVAC Equipment	HVAC Equipment	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Mechanical Equipment	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	Section 12.2.6: Mechanical and Electrical Equipment
Manufacturing Equipment	Manufacturing Equipment	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	N/A	N/A	N/A
Ducts	Ducts	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Ducts	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	Section 12.2.6: Mechanical and Electrical Equipment
Piping	Piping	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Piping	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	Section 12.2.6: Mechanical and Electrical Equipment
Fire Sprinkler Systems	Fire Sprinkler Systems	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	N/A	N/A	Section 12.2.8: Other Hazards
Fire Alarm Systems	Fire Alarm Systems	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Fire Alarm Systems	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	Section 12.2.8: Other Hazards
Emergency Lighting	Emergency Lighting	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Emergency Lighting Systems	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	N/A
Electrical Distribution Equipment	Electrical Distribution Equipment	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Electrical Equipment	Table 2-10: Performance Levels and Permissible Damage - Mechanical/Electrical/Plumbing Systems	Section 12.2.8: Other Hazards

Literature References

Nonstructural Performance Levels—*con't*

System	FEMA 356 System Name	Reference	VISION 2000 System Name	Reference	ATC20 Reference
Light Fixtures	Light Fixtures	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	Light Fixtures	Table 2-9: Performance Levels and Permissible Structural Damage - Architectural Elements	Section 12.2.4: Ceilings and Light Fixtures
Plumbing	Plumbing	Table C1-6: Nonstructural Performance Levels and Damage--Mechanical, Electrical, and Plumbing Systems/Components	N/A	N/A	N/A
Computer Systems	Computer Systems	Table C1-7: Nonstructural Performance Levels and Damage--Contents	Computer Systems	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Desktop Equipment	Desktop Equipment	Table C1-7: Nonstructural Performance Levels and Damage--Contents	N/A	N/A	N/A
File Cabinets	File Cabinets	Table C1-7: Nonstructural Performance Levels and Damage--Contents	File Cabinets	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Book Shelves	Book Shelves	Table C1-7: Nonstructural Performance Levels and Damage--Contents	Bookshelves	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Hazardous Materials	Hazardous Materials	Table C1-7: Nonstructural Performance Levels and Damage--Contents	Hazardous Materials	Table 2-11: Performance Levels and Permissible Damage - Contents	Section 6.1: Wood Frame Dwellings and Small Buildings; Section 12.2.8: Other Hazards
Art Objects	Art Objects	Table C1-7: Nonstructural Performance Levels and Damage--Contents	Art works, collections	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Furniture	N/A	N/A	Furniture	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Office equipment	N/A	N/A	Office equipment	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A
Storage racks & cabinets	N/A	N/A	Storage racks & cabinets	Table 2-11: Performance Levels and Permissible Damage - Contents	N/A

Literature References

Structural Performance Levels

System	FEMA 356 System Name	Reference	VISION 2000 System Name	Reference	ATC20 Reference
Concrete Frames	Concrete Frames	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Concrete frames	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 8.1: Tilt-up Structures; Section 9.2: Cast-in-Place Concrete Building
Steel Moment Frames	Steel Moment Frames	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Steel Moment Frames	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 10.2: Moment-Resisting Steel Frames; Section 10.5: Steel Frame with Cast-in-Place Concrete or Reinforced Masonry Walls
Braced Steel Frames	Braced Steel Frames	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Braced Steel Frames	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 10.1: Braced Steel Frames
Concrete Walls	Concrete Walls	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Concrete shear walls	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 8.1: Tilt-up Structures; Section 9.2: Cast-in-Place Concrete Building; Section 9.2: Cast-in-Place Concrete Building
Unreinforced Masonry Infill Walls	Unreinforced Masonry Infill Walls	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Unreinforced Masonry Infill Walls	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 7.1: Unreinforced Masonry Construction; Section 9.2: Cast-in-Place Concrete Building; Section 10.4: Steel Frame with Unreinforced Masonry Infill Walls
Unreinforced Masonry (Noninfill) Walls	Unreinforced Masonry (Noninfill) Walls	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	URM Bearing walls	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 7.1: Unreinforced Masonry Construction
Reinforced Masonry Walls	Reinforced Masonry Walls	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Reinforced Masonry Walls	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 9.2: Cast-in-Place Concrete Building
Wood Stud Walls	Wood Stud Walls	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Wood Stud Walls	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 6.1: Wood Frame Dwellings and Small Buildings; Section 6.2: Commercial, Institutional, and Industrial Structures

Literature References

Structural Performance Levels—*con't*

System	FEMA 356 System Name	Reference	VISION 2000 System Name	Reference	ATC20 Reference
Precast Concrete Connections	Precast Concrete Connections	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	N/A	N/A	Section 9.3: Precast Element Structures; Section 9.4: Liftslab Structures
Foundations	Foundations	Table C1-3: Structural Performance Levels and Damage--Vertical Elements	Foundations	Tables 2-7a, 2-7b & 2-7c: Performance Levels and Permissible Structural Damage - Vertical Elements	Section 6.1: Wood Frame Dwellings and Small Buildings; Section 6.2: Commercial, Institutional, and Industrial Structures; Section 7.1: Unreinforced Masonry Construction; Section 7.2: Reinforced Masonry Construction; Section 8.1: Tilt-up Structures; Section 9.2: Cast-in-Place Concrete Building; Section 10.1: Braced Steel Frames; Section 10.3: Prefabricated Metal Buildings
Metal Deck Diaphragms	Metal Deck Diaphragms	Table C1-4: Structural Performance Levels and Damage--Horizontal Elements	Metal Deck Diaphragms	Table 2-8: Performance Levels and Permissible Structural Damage - Horizontal Elements	Section 10.1: Braced Steel Frames
Wood Diaphragms	Wood Diaphragms	Table C1-4: Structural Performance Levels and Damage--Horizontal Elements	Wood Diaphragms	Table 2-8: Performance Levels and Permissible Structural Damage - Horizontal Elements	Section 6.1: Wood Frame Dwellings and Small Buildings; Section 6.2: Commercial, Institutional, and Industrial Structures
Concrete Diaphragms	Concrete Diaphragms	Table C1-4: Structural Performance Levels and Damage--Horizontal Elements	Concrete Diaphragms	Table 2-8: Performance Levels and Permissible Structural Damage - Horizontal Elements	Section 7.1: Unreinforced Masonry Construction; Section 9.2: Cast-in-Place Concrete Building; Section 10.4: Steel Frame with Unreinforced Masonry Infill Walls; Section 7.2: Reinforced Masonry Construction; Section 8.1: Tilt-up Structures; Section 9.2: Cast-in-Place Concrete Building
Precast Diaphragms	Precast Diaphragms	Table C1-4: Structural Performance Levels and Damage--Horizontal Elements	N/A	N/A	N/A
Prefabricated Metal	N/A		N/A	N/A	Section 10.3: Prefabricated Metal Buildings
Geotechnical Hazards	N/A		N/A	N/A	Section 11.3: Geotechnical Hazards

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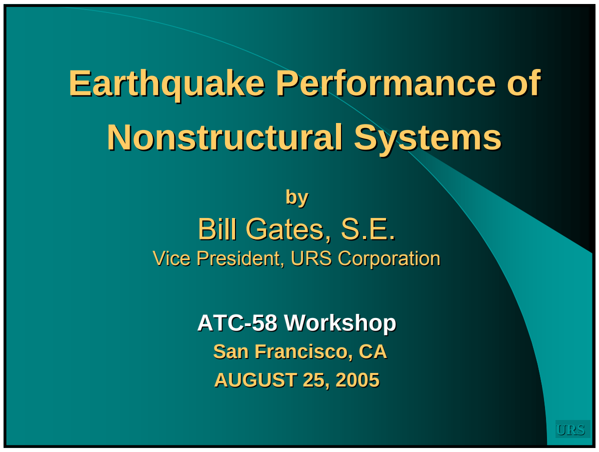
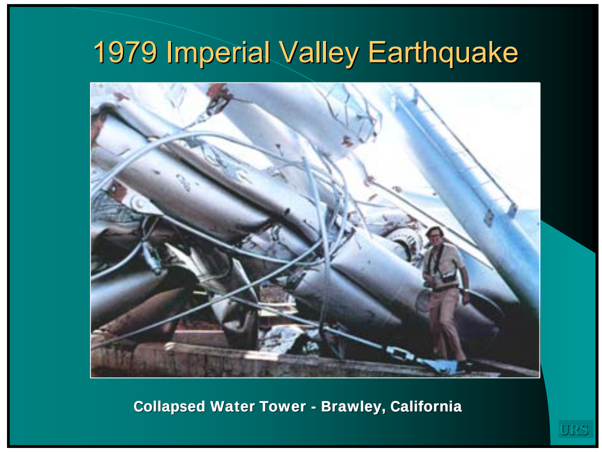
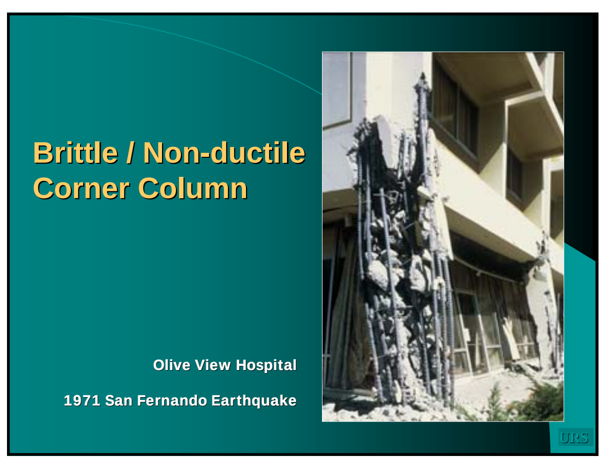

Earthquake Performance of
Nonstructural Systems
by
Bill Gates, S.E.
Vice President, URS Corporation
ATC-58 Workshop
San Francisco, CA
AUGUST 25, 2005
URS


1979 Imperial Valley Earthquake
Collapsed Water Tower - Brawley, California
URS


Stair Tower Collapse on Daycare Wing
Olive View Hospital
1971 San Fernando Earthquake
URS

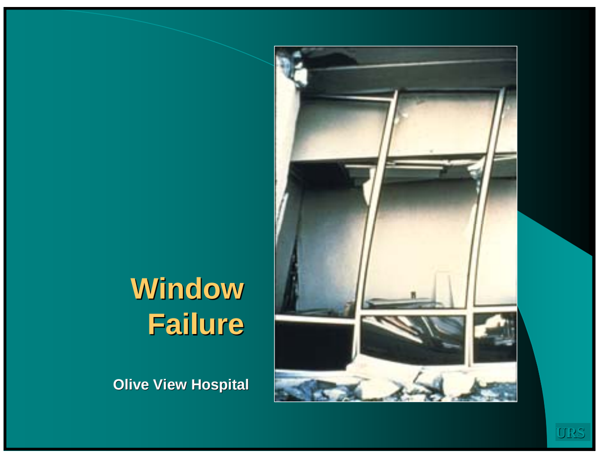

Effects of Tower Collapse
Olive View Hospital
1971 San Fernando Earthquake
URS


Soft First Story Effect
Olive View Hospital
1971 San Fernando Earthquake
URS

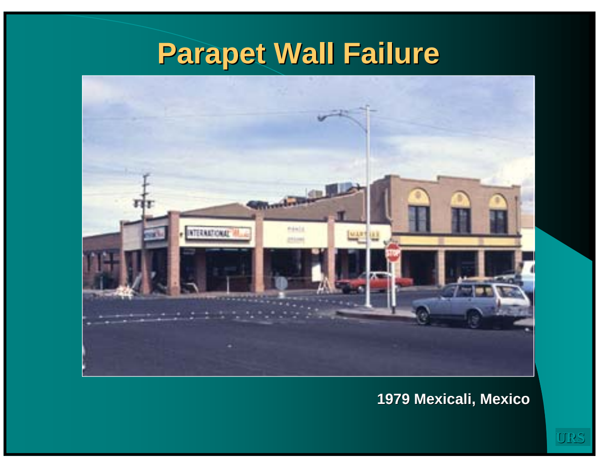

Brittle / Non-ductile
Corner Column
Olive View Hospital
1971 San Fernando Earthquake
URS

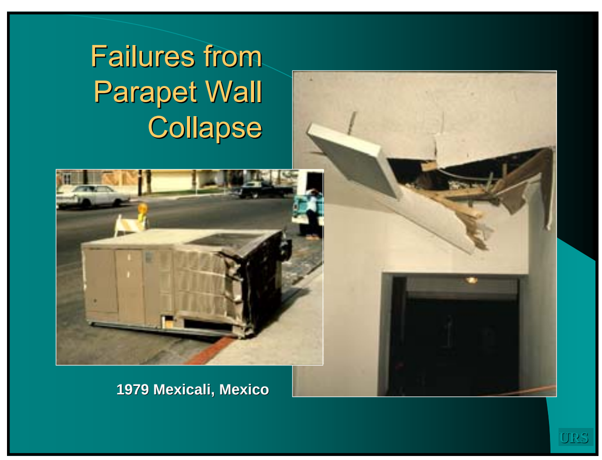

First Floor Cafeteria
Olive View Hospital
1971 San Fernando Earthquake

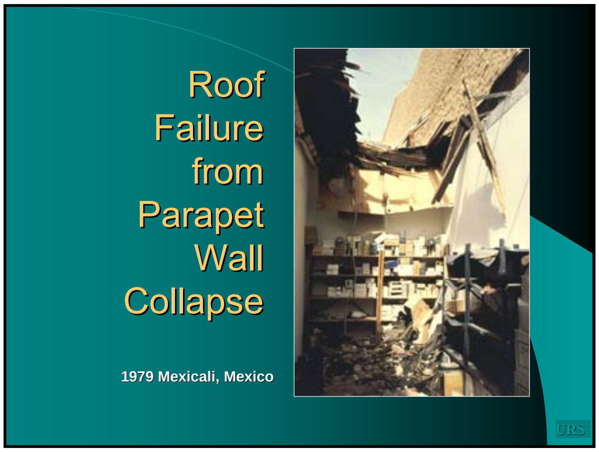

Jammed Elevator Doors
Olive View Hospital
1971 San Fernando Earthquake

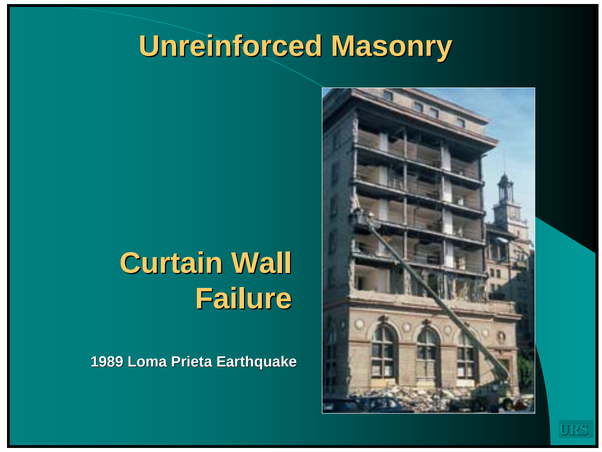

Window Failure
Olive View Hospital

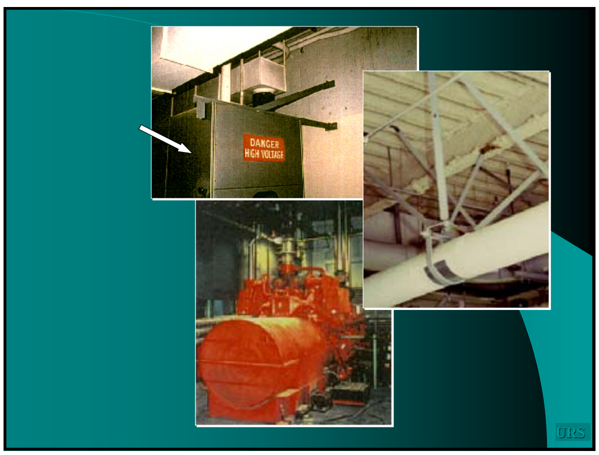

Broken Window
1994 Northridge Earthquake

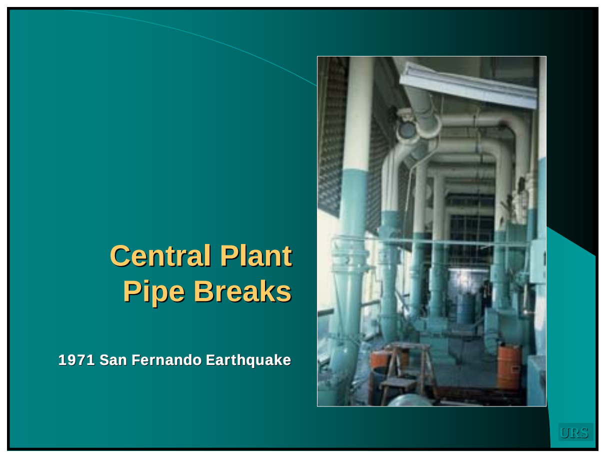

Parapet Wall Failure
1979 Mexicali, Mexico


Failures from Parapet Wall Collapse
1979 Mexicali, Mexico

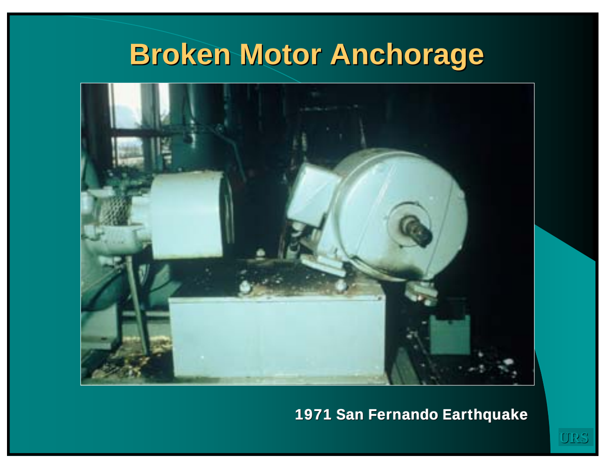

Roof Failure from Parapet Wall Collapse
1979 Mexicali, Mexico

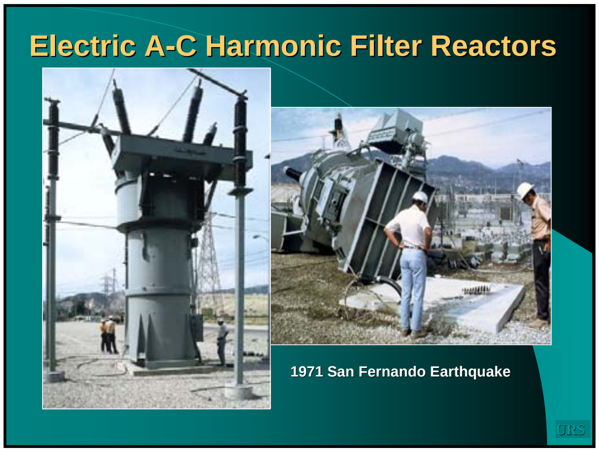

Unreinforced Masonry
Curtain Wall Failure
1989 Loma Prieta Earthquake

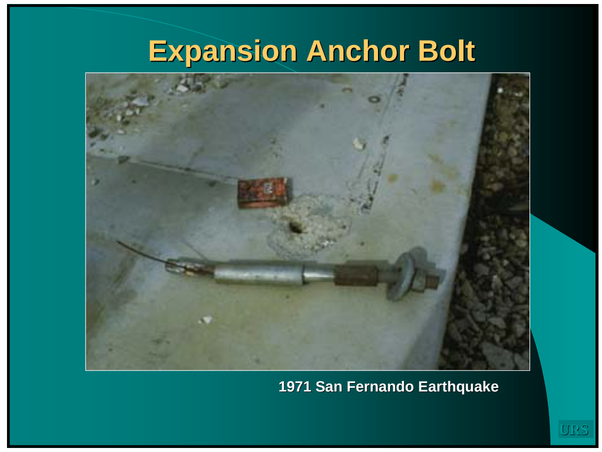

DANGER
HIGH VOLTAGE


Central Plant Pipe Breaks
1971 San Fernando Earthquake


Cast Iron Valve
1971 San Fernando Earthquake


Broken Motor Anchorage
1971 San Fernando Earthquake

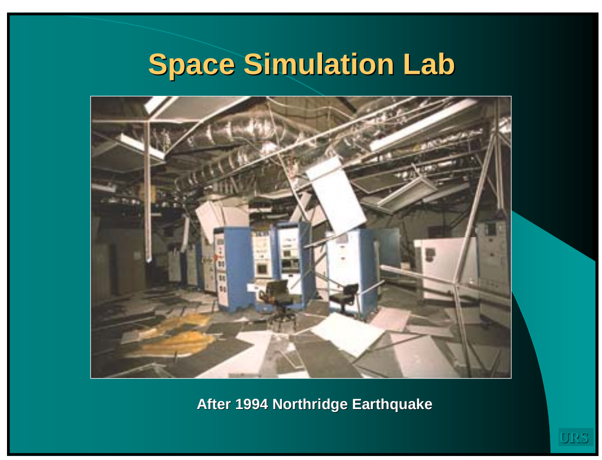

Electric A-C Harmonic Filter Reactors
1971 San Fernando Earthquake


Expansion Anchor Bolt
1971 San Fernando Earthquake

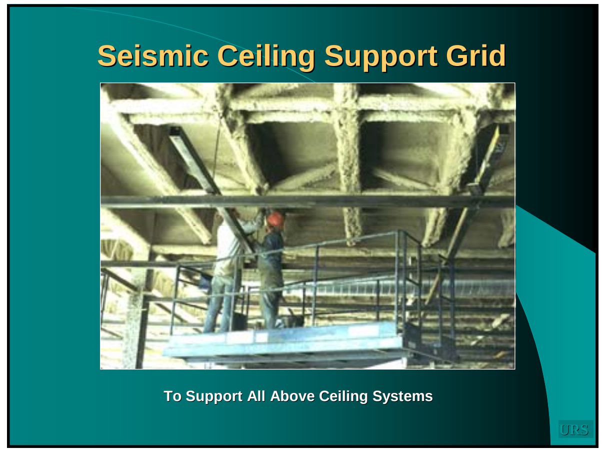

Vane Axial Fan
Olive View Hospital
1994 Northridge

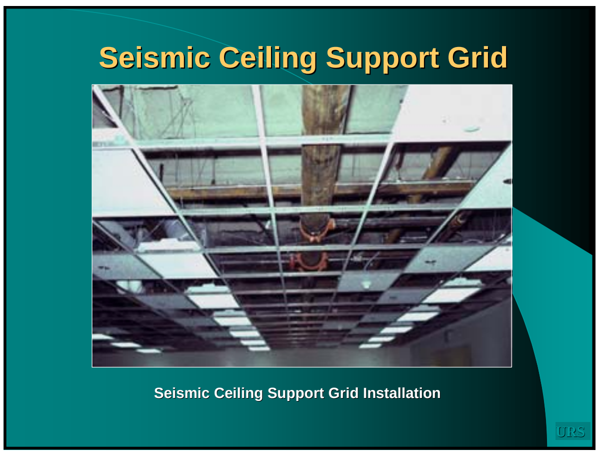

Collapsed Control Room Ceiling
1971 San Fernando Earthquake

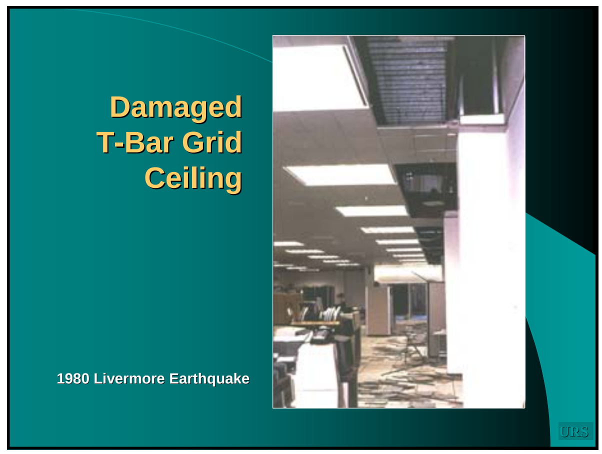

Space Simulation Lab
Before 1994 Northridge Earthquake

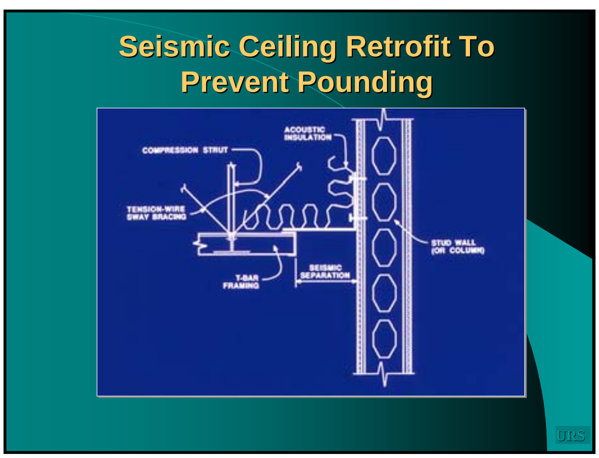

Space Simulation Lab
After 1994 Northridge Earthquake

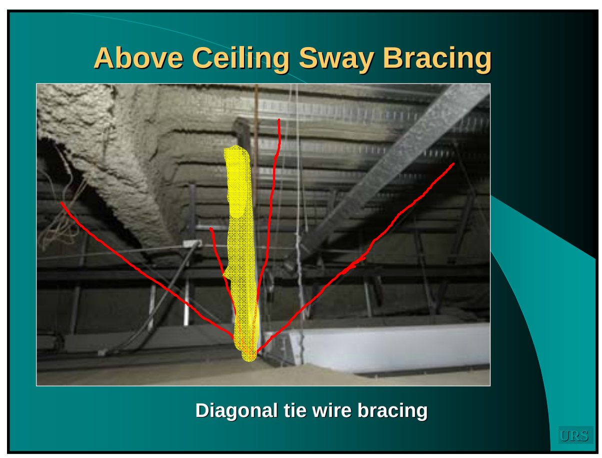

Collapsed Computer Room Ceiling
1965 Seattle Earthquake

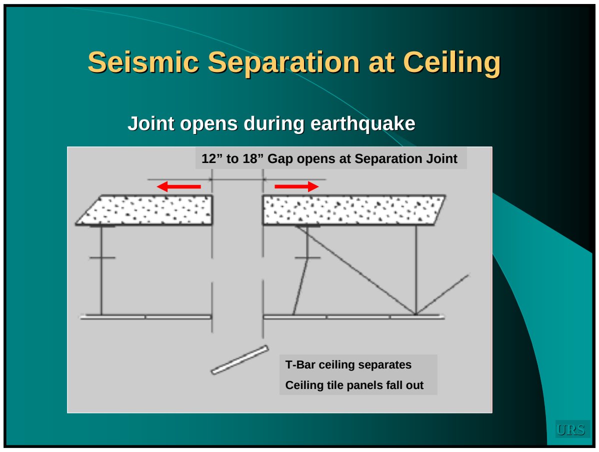

Seismic Ceiling Support Grid
To Support All Above Ceiling Systems

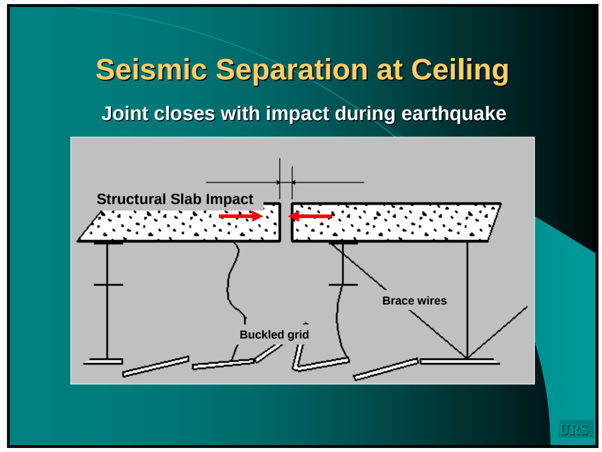

Seismic Ceiling Support Grid
Seismic Ceiling Support Grid Installation

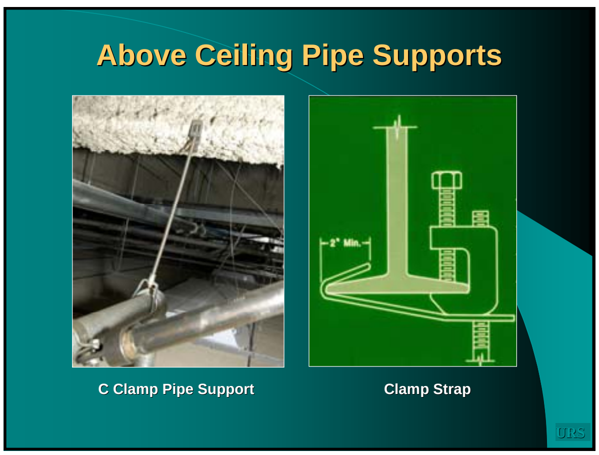

Damaged T-Bar Grid Ceiling
1980 Livermore Earthquake

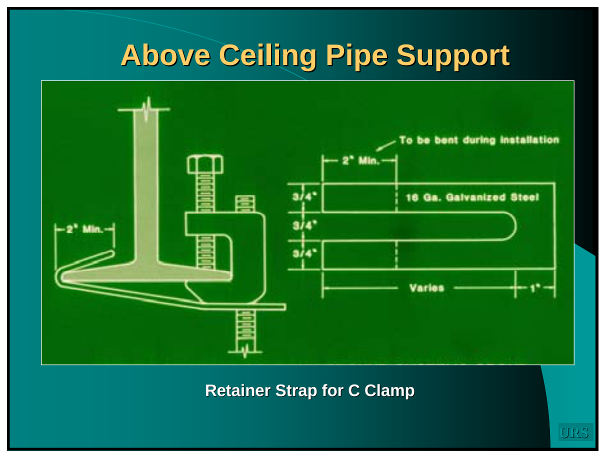

Seismic Ceiling Retrofit To Prevent Pounding
ACOUSTIC INSULATION
COMPRESSION STRUT
TENSION-WIRE SWAY BRACING
STUD WALL (OR COLUMN)
SEISMIC SEPARATION
T-BAR FRAMING


Above Ceiling Sway Bracing
Diagonal tie wire bracing


Seismic Separation at Ceiling
Joint opens during earthquake
12" to 18" Gap opens at Separation Joint
T-Bar ceiling separates
Ceiling tile panels fall out

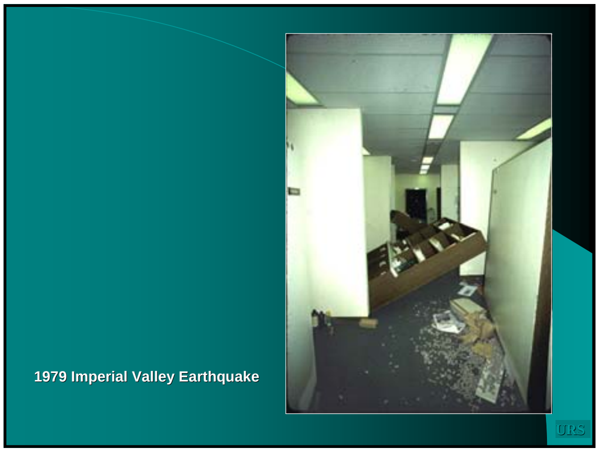

Seismic Separation at Ceiling
Joint closes with impact during earthquake
Structural Slab Impact
Brace wires
Buckled grid


Above Ceiling Pipe Supports
2" Min.
C Clamp Pipe Support
Clamp Strap

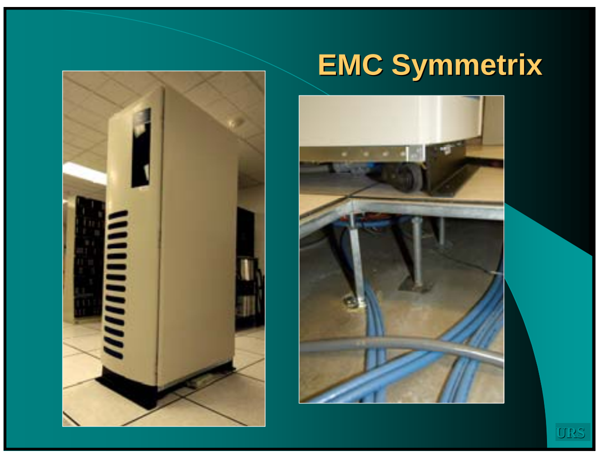

Above Ceiling Pipe Support
To be bent during installation
2" Min.
16 Ga. Galvanized Steel
3/4"
3/4"
3/4"
2" Min.
Varies
1"
Retainer Strap for C Clamp


Computer Floor System
Pedestal Components
Pedestal Assembly


Glued pedestal base will fail

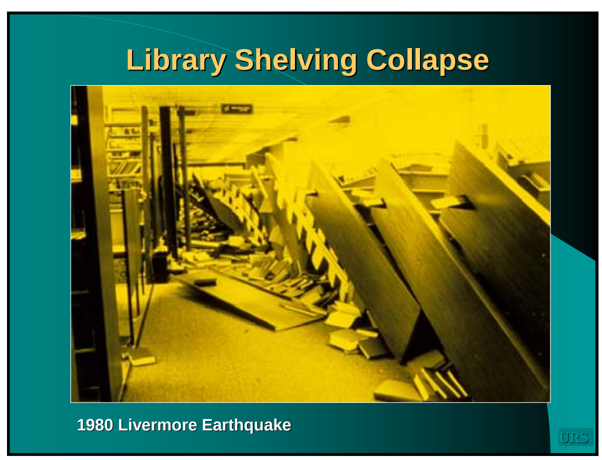

1979 Imperial Valley Earthquake
URS


Major equipment damage in earthquake is due to overturning
Computer Tape Drives
URS


EMC Symmetrix
URS


Sun Work Station
Sun
URS

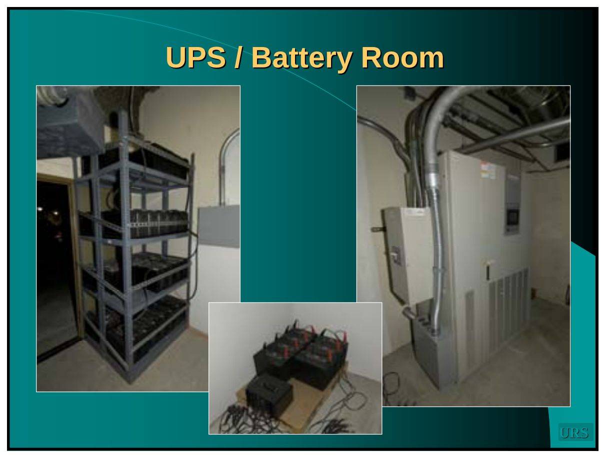

BFS Work Station Rack
URS

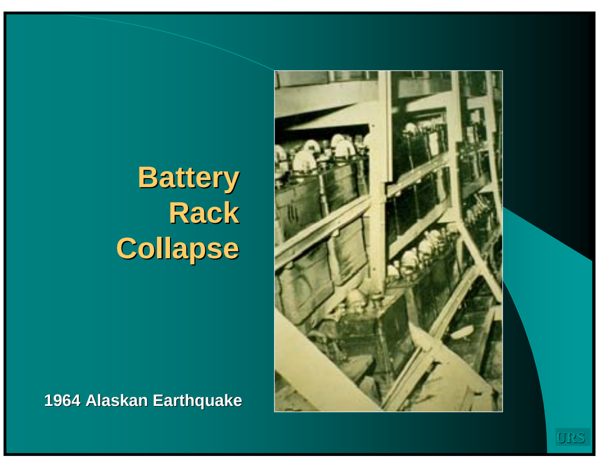

Library Shelving Collapse
1980 Livermore Earthquake
URS

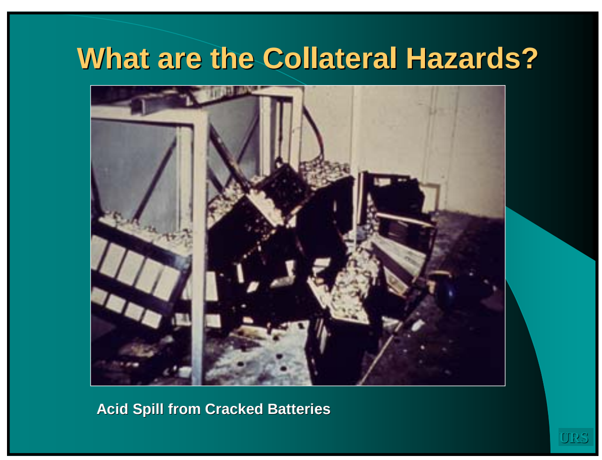

Tape Storage Racks

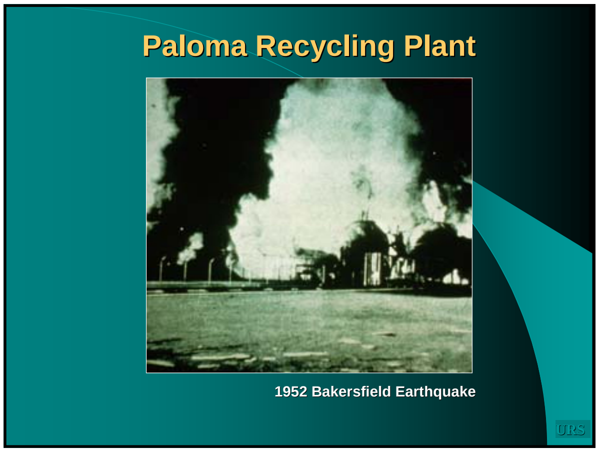

Tape Rack Collapse


Telecom Switch Gear Collapse
1971 San Fernando Earthquake


UPS / Battery Room


Battery Rack Collapse
1964 Alaskan Earthquake


What are the Collateral Hazards?
Acid Spill from Cracked Batteries


Paloma Recycling Plant
1952 Bakersfield Earthquake

Nonstructural Components Based on Past Economic Analysis

J. M. Ferritto

August 2005

John Ferritto

- Naval Civil Engr Lab/NFESC ('69-'00)
- Navy 6.2 Seismic Research Program
- 1982-1984 Economic Analysis
- Chapter 7 NAVFAC P355.2
- Civil Engineering Practice, Volume 1, Structures, Economics of Seismic Design
- 1995 State of California (OSA) SB920
  - EA with new EHMT (Base Isolation)
  - Douglas Way
- California Marine Oil Terminals
  - Chapter 6 Risk and Economics

Objective of Navy Economic Analysis Previous Work

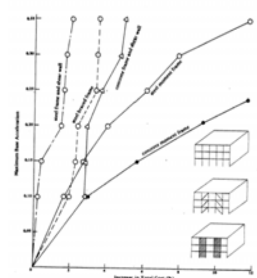
- Navy has large building inventory
- NEHRP retrofitting $$$$$
- New construction design levels ??
- Independent look/approach
- Justification for added strengthening

Cost of Seismic Strengthening

- Martin & Saunders cost estimate
- Used an actual building for data
- Typical Navy construction - 4 story
- Building components
  - Drift vs Acceleration
- Nonstructural components based on cost breakdown categories

- Experienced engineering firm (Walt Saunders)
- Actual basic building -no seismic
  - Add seismic (0.1 to 0.35g at 0.05g increments
  - Elastic limit at each design level
- Various alternative designs
  - Steel and concrete frame
  - Moment frame, braced frame, and shear wall
- Result was a set of specific structural member sizes and detailed component costs

Seismic Costs (New Construction)



Component	Cost ($)	Repair Multiplier
1. Braced frame	126,800	2.0
2. Nonseismic structural frame	625,500	1.5
3. Masonry	417,600	2.0
4. Windows and frames	120,600	1.5
5. Partitions, architectural elements	276,200	1.25
6. Floor	301,200	1.5
7. Foundation	412,100	1.5
8. Building equipment and plumbing	731,600	1.25
9. Contents	500,000	1.05

Typical Displacement Components

Structural
Nonstructural

Component	Cost ($)	Repair Multiplier
1. Braced frame	126,800	2.0
2. Floor and roof	301,200	1.5
3. Ceiling and lights	288,500	1.25
4. Building equipment and plumbing	731,600	1.25
5. Elevators	57,000	1.5
6. Foundation	412,100	1.5
7. Contents	500,000	1.05

Typical Acceleration Components

Structural
Nonstructural

Nonstrucural Elements based On Cost Estimate

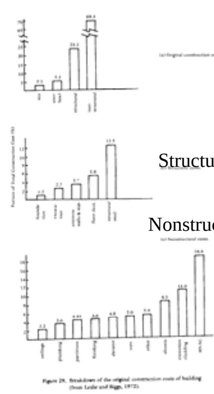
- Walls/Partitions/Masonry Infill
- Nonseismic frame
- Floor/roof
- Foundation
- Windows and Frames
- Ceiling and Lights
- Plumbing, Electrical, and HVAC
- Elevators/Stairs
- Contents

Component Damage

- Drift Components
- Acceleration Components

References

- Whitman (1973) Damage Probability Matrices MIT R73-57 R8
- Culver et al. (1975) Natural Hazards Evaluation NBS BSS61
- Leslie & Biggs (1972) Optimum Seismic Protection MIT No 341 May
- Pate' (1979) Acceptance of Social Cost, USNCEE Stanford Aug
- Walker (1977) Automated Design UC Berkeley EERC 77-12



Site
Overhead
Structural
Nonstructural

Structural

Foundation
Excavation
Concrete walls & slabs
Floor deck
Structural steel

Nonstructural

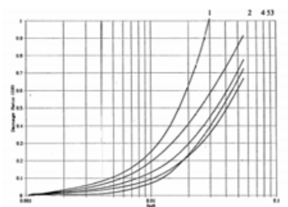
Ceilings
Plumbing
Partitions
Finishing
Elevator
Core
Other
Electric
Extension Cladding
HVAC

Table 13. Cost Increase for Increasing Seismic Force Design Levels (from Leslie et al., 1972)

Item	Percentage Total Cost of Item (%)	Increase Over Original Total Construction Cost (%) for Zones --			
		1	2	3	4
Structural					
Structural Steel[a]	12.5	-	0.171	2.68	5.4[b] 6.6[c]
Foundation[a]	1.2	-	0.162	0.162	0.162
Concrete Walls and Slab[a]	3.7	-	0.024	0.09	0.102
Composite Deck[a]	5.8	-	-	-	-
Total Structural	23.2	-	0.36	2.93	5.66[b] 6.86[c]
Nonstructural					
Masonry Core[a]	5.0	0.55	0.55	0.55	0.71
Precast Panels[a]	4.73	-	0.024	0.033	0.067
Plumbing	3.6	-	-	0.022	0.022
HVAC	18.8	-	0.032	0.15	0.197
Electrical (including lights)	8.5	-	0.022	0.104	0.104
Elevators	4.8	-	0.027	0.131	0.165
Window Systems	4.5	-	-	-	0.627[d]
Partitions	4.45	-	0.012	0.163	0.163
Acoustical Ceilings	2.2	-	-	0.114	0.163
Miscellaneous Metals	3.7	-	0.07	0.089	0.089
Total Nonstructural	68.35	0.55	0.74	1.36	2.31
Total Code Design (code design items)	32.93	0.55	0.934	3.513	6.437[b] 7.637[c]
Maximum Design[e]	91.55	0.55	1.10	4.29	7.97[b] 9.17[c]

[a]Code design.
[b]Using built-up members.
[c]Using WF 27 girders.
[d]New window system.
[e]Total structural and nonstructural items.

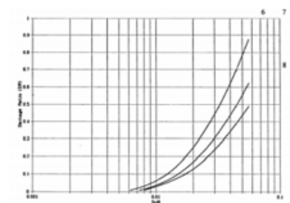
Drift Damage



1. Masonry Walls
2. Concrete Shear Walls
3. Concrete Moment Frames
4. Steel Braced Frames
5. Steel Moment Frames

Figure 4. Damage as a function of drift and acceleration. (based on Way (1995))

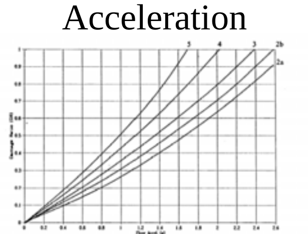
Drift Continued



6. Structural Frames
7. Structural Floors
8. Foundations

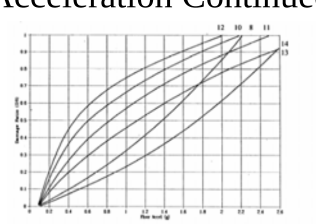
Figure 4. Continued.

Acceleration



5. Steel Moment Frames
4. Steel Braced Frames
2a. Steel Frames w/ CSW
3. Concrete Moment Frames
2b. Concrete Frames w/ CSW
CSW - Concrete Shear Walls

Acceleration Continued



13. Floor Finish & Roof
10. Partitions & Ceilings
11. Mechanical & Electrical
9. Architectural Glass
14. Elevators
8. Foundation and Site Work
12. Contents

Other Loss Costs

Injury and Death

- Historical correlation
  - millions of dollars lost vs number killed
- Ratio Injured vs killed
- Dollar value of life
- Building Occupance Average
- Use local data for consistent building type
- References- ATC-13 and ATC-21

Loss of Use

- Annual salary of all employees as a measure of value of service
- Revenue generated
- Cost of function replacement
- Ability to relocate function
- “Mission Critical”

GSA

- Source of interesting information
- Janatorial cost over life of building exceeds building cost
- Design choice vs. operational cost

NFESC Site

http://www.nfesc.navy.mil/pub_news/abstract.htm

TR 2103-SHR "Seismic Criteria for California Marine Oil Terminals", July 1999, John Ferritto, Stephen Dickenson, Nigel Priestley, and Craig Taylor with Appendices by Douglas Burke, William Seelig, and Shawn Kelly

TR-2055-SHR "Economic Analysis Procedure For Earthquake Hazard Mitigation" by J. M. Ferritto Feb 1997

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- Ferritto, J. (1983) Technical Note N 1671, "An Economic Analysis of Earthquake Design Levels For New Construction", July 1983
- Ferritto, J (1984a) "Economics of Seismic Design for New Building", American Society of Civil Engineers Journal of the Structures Division, ASCE Journal of Structural Engineering Vol. 110 No. 12 Dec. 1984
- Ferritto, J (1984b) "Economics, Expected Damage and Costs of Seismic Strengthening", 8th World Conference on Earthquake Engineering, San Francisco July 1984
- Way, D (1995) “Earthquake Hazard Mitigation Technology Guidelines” prepared for Division of the State Architect, State of California, by Base Isolation Consultants, San Francisco.
- TR-2055-SHR "Economic Analysis Procedure For Earthquake Hazard Mitigation" by J. M. Ferritto Feb 1997

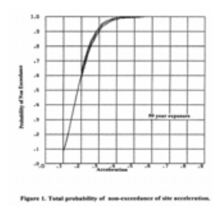
Discussion

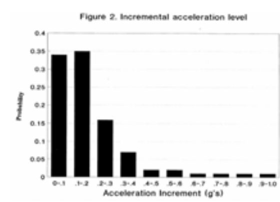
Questions?

The End

Analysis Procedure

Seismic Hazard Exposure

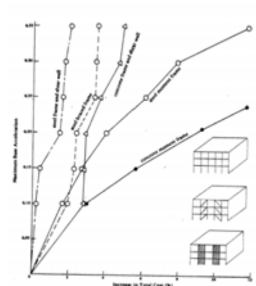




Present Worth Analysis

- Total Costs Include:
  - Seismic Strengthening (Initial)
  - Sum of Structural Component Damage (PW)
  - Loss of Use Costs (PW)
  - Injury and Death (PW)

Seismic Strengthening Cost



Select a strengthening system, design level, and estimate cost

Damage Cost

- For a given design level (MF 0.2g for example)
  - Conduct series of analyses (in increments from 0 to peak g level)
  - For each analysis
    - Calculate drifts and floor accelerations
    - Calculate component damage ratio

For a given design level and analysis level
Total Building Damage = Σ (Damage Ratio) * (Component Cost)* (Component Repair Multiplier)

Sustained Damage

- Single peak vs sustained repeated levels
- Reference for effective response level
- 65 % of peak used

Table of Damage

Compute damage (Drift + Acceleration) for each design level and each load level

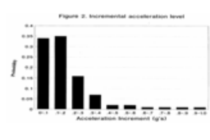
Design Level G's	Applied Load Level G's									
	0	0.05	0.15	0.25	0.35	0.45	0.55	0.65	0.75	0.85
0.10										
0.15										
0.20										
0.25										
0.30										
0.35										

Or alternatively for each design alternative

Expected Damage

Use seismic exposure to compute expected damage

Expected Building Damage = Σ (Total Building Damage for increment "bin" of acceleration) * (Acceleration "bin" Probability)



Design Level G's	Applied Load Level G's									
	0	0.05	0.15	0.25	0.35	0.45	0.55	0.65	0.75	0.85
0.10										
0.15										
0.20										
0.25										
0.30										
0.35										

Present Worth of Future Damage

Select interest rate

Current Expected Damage Costs = PV(Expected Building Damage Cost)

Results Sensitive to Interest rate
Long Term Bond rate

		Braced Frame		Frame & Shear Wall	
Acceleration Increment (g's)	(1) Probability	(2) Damage Ratio Braced Frame	(1) x (2) Probable Damage Ratio	(3) Damage Ratio Shear Wall	(1) x (3) Probable Damage Ratio
0-.1	0.34	0.03	0.0102	0.015	0.0051
.1-.2	0.35	0.11	0.0385	0.05	0.0175
.2-.3	0.16	0.175	0.028	0.08	0.0128
.3-.4	0.07	0.25	0.0175	0.11	0.0077
.4-.5	0.02	0.305	0.0061	0.14	0.0028
.5-.6	0.02	0.335	0.0067	0.17	0.0034
.6-.7	0.01	0.365	0.00365	0.19	0.0019
.7-.8	0.01	0.41	0.0041	0.22	0.0022
.8-.9	0.01	0.45	0.0045	0.24	0.0024
.9-1.0	0.01	0.485	0.00485	0.26	0.0026
Total Damage Ratio		BF =	0.1241	SW =	0.0584

For 50 years of equal exposure the average Present Worth factor is 0.28

The present value of the damage costs are:

Braced Frame 0.28 * 0.1241 * $ 5,928,800 = $206,000

Shear Wall 0.28 * 0.0584 * $ 5,876,700 = $96,000

Automated Approach

- Drain2d/Drain3d
- Automate input generation
- Read output files and extract required peak values
- Minimize labor

Observation

- Stiffening reduces drift damage but increases acceleration damage
- Variation in period of structure with increase in design level

Opportunities for Improvement

- Improve / automate damage estimation
  - Time histories of displacement & acceleration
  - Fatigue based numerical index of damage
  - post-process time histories automatically
- Update Damage Ratio criteria
- Expand cost data

Variations on Procedure

- Adaptable to response spectra techniques
- Use specific set of design events rather than seismic probability distribution

Attachment H

ATC-58
Development of Next-Generation Performance-Based
Seismic Design for New and Existing Buildings

Nonstructural Workshop
San Francisco, August 25, 2005

Comments on "Data Points" From the Past

CUREE

Bob Reitherman, Executive Director
Consortium of Universities for Research in Earthquake Engineering

"Performance"

- "Performance" really means "high performance"
  - emphasis on going beyond code minimums, beyond relatively prescriptive requirements, beyond traditional life safety criteria
  - Nonstructural component lists are intended to improve performance/criteria (e.g., it is rare to use performance-based engineering to argue that code minimums are too high)
- "Performance-based seismic design" really means "design based on quantitative estimates of seismic performance" (i.e., loss estimation)

Structural vis-à-vis Nonstructural Design

- Nonstructural seismic design is largely a matter of designing retrofits--even for new construction
  - e.g., the design and installation of a new suspended ceiling in LA is the same as in LA

Structural vis-à-vis Nonstructural Design

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  - e.g., the design and installation of a new suspended ceiling in LA is the same as in LA

(Los Angeles) (Louisiana)

Structural vis-à-vis Nonstructural Design

- Nonstructural seismic design is largely a matter of designing retrofits--even for new construction
  - e.g., the design and installation of a new suspended ceiling in LA is the same as in LA

(Los Angeles) (Louisiana)

(where, in effect, a seismic retrofit is added to the basic design)

Structural vis-à-vis Nonstructural Design

- In Los Angeles and in Louisiana, a ceiling system is specified that meets architectural needs for:
  - Cost
  - Aesthetics
  - Sound (Noise Reduction Coefficient, Sound Transmission Loss, Reverberation Time)
  - Fire (ASTM E-84: flame spread, smoke generation; fire resistance)
  - Light (reflectance, color)
- And then in Los Angeles, extra wires , edge details, etc. are added to the design to make it seismic

Structural vis-à-vis Nonstructural Design

- Structural seismic design is not largely a matter of designing retrofits for new buildings
  - (e.g., designing an EBF or ductile RC frame is completely different from the start than designing non-seismic structures)
- Need to bring more innovation to the nonstructural portion of the earthquake problem
  - Products as well as design: seismic "design" guidelines must be usable by industries as goals as well as designers
  - Guidelines must provide for future testing and development, not just rely on lists of currently used nonstructural components

How we got here

1778 **complete water system for buildings** (Joseph Bramah, water closet added to pressurized water piping dating back to Romans)

How we got here

1851 **complete metal skeleton** - changing role of walls to nonstructural purpose (Crystal Palace, London, Joseph Paxton, 1851; 1855 McCullough Shot Tower, new York, James Bogardus; 1865 St. Oouen Docks, Paris, Hippolyte Fontaine; 1885 Home Insurance Building, Chicago, William le Baron Jenney; 1918, Hallidie Building, San Francisco, Willis Polk)

How we got here

1853 **elevator** (P.T. Barnum's Crystal Palace, New York, Elisha Graves Otis, 1853 - demonstration of safety brake)

How we got here

1874 **automatic fire sprinklers** (Parmalee Piano Factory, New Haven, Henry Parmalee)

How we got here

1878 **electric light and power** (incandescent light bulb, John Swan, 1878; first long-lasting incandescent light bulb 1879; distribution system, Edison Co., London and New York, 1882; fluorescent lamp, Westinghouse and GE, 1938)

How we got here

1906 **suspended ceiling** (Kuhn and Loeb Bank, New York, A. M. Feldman, 1906; Drake University Laboratories, Des Moines, Saarinen Swanson and Saarinen, 1947; GM Technical Center, Warren, MI, Saarinen Swanson and Saarinen, 1950)

How we got here

1922 **air conditioning** (Grauman's Theater, Los Angeles, Willis Carrier, 1922)

How we got here…but we're not there yet.

1778

1851

1878

1906

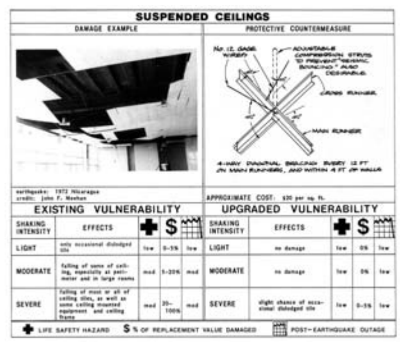
1922

These are old nonstructural technologies, and all were invented and popularized without any thought of earthquakes.

Performance-based seismic design as a way to motivate improvements, not just to better analyze current conditions.

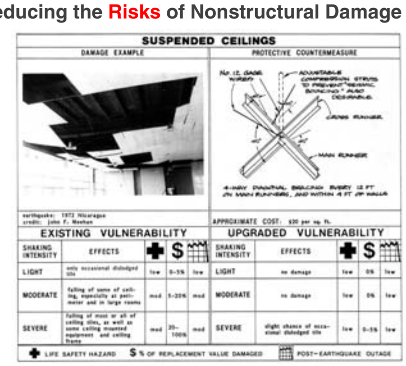
Reducing the Risks of Nonstructural Damage

FEMA 74, 1983



Reducing the **Risks** of Nonstructural Damage

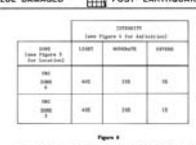
FEMA 74, 1983



Reducing the Risks of Nonstructural Damage

EXISTING VULNERABILITY					UPGRADED VULNERABILITY				
SHAKING INTENSITY	EFFECTS	✚	$	[outage]	SHAKING INTENSITY	EFFECTS	✚	$	[outage]
LIGHT	only occasional dislodged tile	low	0–5%	low	LIGHT	no damage	low	0%	low
MODERATE	falling of some of ceiling, especially at perimeter and in large rooms	mod	5–20%	mod	MODERATE	no damage	low	0%	low
SEVERE	falling of most or all of ceiling tiles, as well as some ceiling mounted equipment and ceiling frame	mod	20–100%	mod	SEVERE	slight chance of occasional dislodged tile	low	0–5%	low

✚ LIFE SAFETY HAZARD $ % OF REPLACEMENT VALUE DAMAGED [outage] POST–EARTHQUAKE OUTAGE



Reducing the Risks of Nonstructural Damage

Figure 8 : Nonstructural Examples

FEMA 74, 1994, 3rd ed.

Detail	Nonstructural Item	Type of Detail	Page
U	BUILDING UTILITY SYSTEMS		
U2	Batteries and Battery Rack	Engineering Required	30
U3	Diesel Fuel Tank	Engineering Required	31
U8	Electrical Bus Ducts and Primary Cable System	Engineering Required	32
U10	Fire Extinguisher and Cabinet	Do-It-Yourself	33
U15	Propane Tank	Engineering Required	34
U19a	Water Heater: Corner Installation	Do-It-Yourself	35
U19b	Water Heater: Wall Installation	Do-It-Yourself	36
U21	Piping	Engineering Required	37
U29	Chiller	Engineering Required	38
U32	Air Compressor (or other HVAC Equipment)	Engineering Required	40
U35	Suspended Space Heater	Engineering Required	41
U36	HVAC Distribution Ducts	Engineering Required	42
U37	Air Diffuser	Do-It-Yourself	43
U38	Residential Chimney	Engineering Required	44

Reducing the Risks of Nonstructural Damage

FEMA 74, 1994, 3rd ed.

A	ARCHITECTURAL ELEMENTS		
A2a	Built-In Partial-Height Partitions	Engineering Required	45
A2b	Built-In Full-Height Partitions	Engineering Required	46
A3	Suspended T-Bar Ceilings	Engineering Required	47
A5a	Suspended Light Fixtures	Do-It-Yourself	48
A5b	Pendant Light Fixtures	Do-It-Yourself	49
A9	Stairways	Engineering Required	50
A12	Windows	Engineering Required	51
A15a	Unreinforced Brick Parapets	Engineering Required	52
A15b	Veneer	Engineering Required	53
A16	Freestanding Walls or Fences	Engineering Required	54
A21	Exterior Signs	Engineering Required	55

Reducing the Risks of Nonstructural Damage

FEMA 74, 1994, 3rd ed.

Detail	Nonstructural Item	Type of Detail	Page
C	FURNITURE AND CONTENTS		
C8	Large Computers and Access Floors	Engineering Required	56
C10	Desktop Computers and Office Equipment	Do-It-Yourself	57
C12a	Tall Shelving	Engineering Required	58
C12b	Library Stacks	Engineering Required	59
C12c	Tall Shelving: Wall Unit	Do-It-Yourself	60
C13	Tall File Cabinets	Do-It-Yourself	61
C18	Flexible Connection for Gas or Fuel Lines	Do-It-Yourself	62
C19	Drawer and Cabinet Latches (Kitchen, Office, Laboratory, etc.)	Do-It-Yourself	63
C20	Freestanding Wood Stove	Do-It-Yourself	64
C21	Compressed-Gas Cylinders	Do-It-Yourself	65
C22	Containers of Hazardous Materials	Engineering Required	66
C26	Fragile Artwork	Do-It-Yourself	67
C27	Freestanding Half-Height Partitions	Do-It-Yourself	68
C28	Miscellaneous Furniture	Do-It-Yourself	69

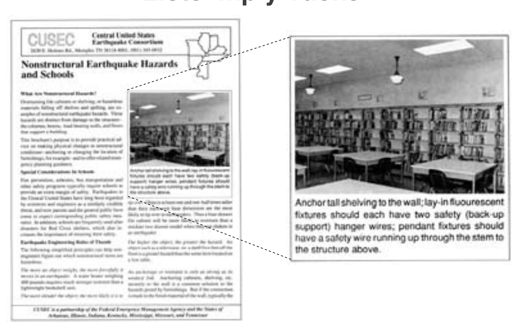
Reducing the **Risks** of Nonstructural Damage

- If we quantify the risk of injury, who will use the numbers?
  - John Wiggins, "Death Risk" and the Long Beach City Council
- "Best practice," meeting a safety standard, vs. sliding scale of calculated casualties as a design tool (and as a usable service for consumer)

Lists Imply Tasks

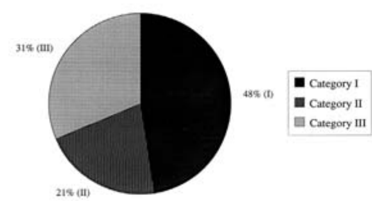
- Short lists vs. long lists: which are better?
  - Idaho schools: "short form" vs. "long form"
  - What to advise in central US for retrofitting schools?
  - Berkeley School District: "Category I" hazards vs. Category II and Category III hazards

Lists Imply Tasks



Example: 18 schools in Berkeley Unified School District, approx. 1 million sq. ft.

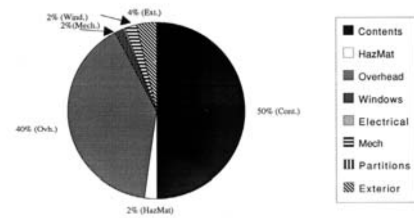
FIGURE 2: PERCENTAGE OF TOTAL DISTRICT COST, BY HAZARD CATEGORY



Reitherman Company and Oak Engineering, 1990

Example: 18 schools in Berkeley Unified School District, approx. 1 million sq. ft.

FIGURE 3: PERCENTAGE OF TOTAL DISTRICT COST, BY ITEM GROUPINGS: ONLY FOR HAZARD CATEGORY I



Reitherman Company and Oak Engineering, 1990

Lists Imply Tasks

- Short lists vs. long lists: which are better?
  - Idaho schools: "short form" vs. "long form"
  - What to advise in central US for retrofitting schools?
  - Berkeley School District: "Category I" hazards vs. Category II and Category III hazards
- Lists useful for prioritizing research
  - Experimentation
  - Post-earthquake data gathering and analysis

High Priorities in Lists for Research

Table 3: Estimated Costs to Conduct Improved Nonstructural Post-Earthquake Data Collection and Organization

Level of Effort	1/2 N	N	2N	4N
actual	$69,000	$275,000		
proposed system of data collection	$500,000	$750,000	$1,125,000	$1,500,000

Note (see also text) N is the overall direct property damage level of the Northridge Earthquake, approximately $40 billion; 1/2 N-actual is the 1989 Loma Prieta Earthquake.

R. Reitherman, "The Need for Improvement in Post-earthquake Investigations of the Performance of nonstructural Components," ATC-29, *Seminar and workshop on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures,* 1992.

Difference in Lists: New vs. Existing

- **New:** lists are usually divided up by discipline (actually by contract--not whether the item is "architectural" or not but whether it appears on the A-sheets and is signed off by the architect)
  - **Contents:** (occupant-introduced items) often excluded for good scope reasons (post-occupancy permit, hard to manage, requires management of occupants, not the design professional's or building contractor's or building official's problem, etc.) **but** contents are a a big part of performance/loss
- **Existing:** lists can be divided up by how the retrofit work will get done (e.g., fix all overhead components at one time in classrooms) or by loss estimation categories (e.g., list of items that are essential for the EOC; list of items in museum that are especially high value)

A list organized according to how retrofitting will proceed

TABLE 2
ESTIMATED NONSTRUCTURAL HAZARD REDUCTION COSTS, BY TYPE OF NONSTRUCTURAL ITEM, ONLY FOR HAZARD CATEGORY I

Type of Item	Category I Cost	Cost as % of Total Hazard Category I Cost
Contents & Equipment	$428,450	50%
Hazardous Materials	19,197	2%
Overhead	342,195	40%
Windows	15,103	2%
Electrical Equipment	450	<1%
Mechanical Equipment	19,500	2%
Partitions	0	0%
Exterior	30,000	4%
Total	$854,805	100%

A list organized according to how retrofitting will proceed

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Total	$854,805	100%

Teacher issues

With fire dept. help

Work disrupts usage of room

Done by one speciality vendor,under one contract

Work can occur without disrupting interior usage

Conclusion (question): Lists for What?

- Lists for what purposes?
- Inevitably: limitations of scope; "fine print" disclaimers will do a disservice; need to communicate not just to designers but to owners/clients/consumers/regulators what performance they're getting
- Inevitably: must be practical limits on the tasks that are implied by lists; let's not add "the kitchen sink"

Building-Component Taxonomy

Keith Porter
ATC-58 Workshop
25 August 2005
SGH, San Francisco

Contents

- Occupancies in scope
- 10 Objectives
- Existing taxonomies reviewed
- Selected taxonomy: NISTIR 6389
- Required extension for seismic & other features
- Sample of taxonomy

Occupancies

ATC-58 Occupancy	Equivalent HAZUS occupancy classes
Multifamily dwellings	RES3 Multi-Family Dwelling
Temporary lodgings and institutional dormitories	RES4 Temporary Lodging RES5 Institutional Dormitory
Retail trade	COM1 Retail Trade
Warehouse and warehouse retail	COM2 Wholesale Trade
Professional and technical services and government offices	COM4 Professional and Technical Services GOV1 General Services
Hospitals	COM6 Hospital
School classrooms and administration	EDU1 Grade Schools EDU2 Colleges and Universities
University laboratory research	EDU2 Colleges and Universities

10 objectives

1. Clear.
   No circular or subjective definition
2. Common fragility.
   Same EDP, DM, capacities.
3. Distinguish performance.
   E.g., braced vs. unbraced equipment
4. Testable.
   Can quantify fragility with a single research project.
5. Can assess consequences.
   E.g., in terms of D^3
6. Flexible.
   Does not presuppose future findings; allow additions
7. Collectively exhaustive.
   A place for everything. Need not be MECE
8. Simple.
   Relatively few categories
9. Collapsible.
   E.g., by performance group, EDP, occupancy…
10. Familiar.
    For ease of communication with contractors, engineers, cost estimators

Taxonomies reviewed

	1. Clear definitions	2. Collectively exhaustive	3. Common fragility functions	4. Testable	5. Distinguishes performance	6. Simple	7. Assessment of consequences	8. Collapsible	9. Flexible	10. Familiar
IBC 2000; ASCE 7-05	◐	●	●	●	●	⊙	●	●	◐	⊙
HAZUS	⊙	◐	⊙	◐	●	⊙	⊙	●	●	⊙
Porter (2000)	⊙	◐	⊙	⊙	⊙	●	⊙	⊙	◐	⊙
Taghavi and Miranda (2003)	⊙	◐	●	⊙	●	●	⊙	⊙	◐	⊙
Antaki (2004)	●	●	⊙	●	⊙	◐	●	⊙	●	◐
UNIFORMAT II	◐	⊙	●	●	●	⊙	●	⊙	◐	⊙
NISTIR 6389 (proposed for use here)	⊙	⊙	⊙	⊙	●	◐	⊙	⊙	◐	⊙
MasterFormat 04	⊙	◐	⊙	⊙	●	●	⊙	●	◐	⊙
RS Means assemblies	⊙	⊙	⊙	⊙	●	●	⊙	⊙	◐	⊙
RS Means components	⊙	⊙	●	⊙	●	●	⊙	⊙	◐	⊙

⊙ = true ◐ = somewhat true ● = untrue

NISTIR 6389 (NIST 1999)

- Extension of UNIFORMAT-II (ASTM 2002)
  - One of 2 major construction specification systems, with MasterFormat (CSI 2004)
  - UNIFORMAT-II: system orientation (60 items)
  - CSI MasterFormat: material, trade orientation; (170 pp.)
- NISTIR 6389 adds a 4th level of detail
  - Numbering A0000
  - 280 items (4 pp.)

Level 1 Major Group Elements	Level 2 Group Elements
A SUBSTRUCTURE	A10 Foundations
	A20 Basement Construction
B SHELL	B10 Super Structure
	B20 Exterior Enclosure
	B30 Roofing
	B40 Exterior Finishes
C INTERIORS	C10 Interior Construction
	C20 Stairs
	C30 Interior Finishes
D SERVICES	D10 Conveying
	D20 Plumbing
	D30 HVAC
	D40 Fire Protection
	D50 Electrical
E EQUIPMENT & FURNISHINGS	E10 Equipment
	E20 Furnishings
F SPECIAL CONSTRUCTION & DEMOLITION	F10 Special Construction
	F20 Selective Building Demolition

Red = all nonstructural
Yellow = some nonstructural

For seismic & other attributes, propose level-5 extension

- Format A0000.000
  - Default ".000" for undifferentiated NISTIR 6389 group
  - Level-5 (001, 002, …) reflects design & retrofit features
  - E.g., restrained vs. unrestrained components
- Add 001, 002, … at will
  - Interactive database was created w/ fragilities, costs
  - Lit review of tests, recon reports was performed to reflect some important distinctions
  - Currently contains ~390 items

Sample of proposed taxonomy

Level 1 ID, descr.	Level 2 ID, descr.	Level 3 ID, descr.	Level 4 ID, description	Level 5 ID, description
B Shell	B20 Ext. Enclosure	B2020 Ext. Windows	B2021 Windows	B2021.000 Windows, all
				B2021.001 Window, Al frame, sliding, std glass, 1-25 sf pane
				B2021.002 Window, Al frame, fixed, std glass, 80"x80" pane
				B2021.003 Windows, wood, double hung, standard glass, 3'-1.5"x4'
				B2021.004 Window, AL frame, sliding, heavy sheet glass, 4'-0x2'-6"x3/16"
			B2022 Curtain Walls	B2022.000 Curtain Walls, all
				B2022.001 Highrise curtain-wall systems with annealed glass
				B2022.002 Highrise curtain-wall systems with tempered, wired, or laminated glass, or glass with shatter-resistant film
			B2023 Storefronts	B2023.000 Storefronts, all
				B2023.001 Lowrise storefront windows with annealed glass
				B2023.002 Lowrise storefront windows with tempered, wired, or laminated glass, or glass with shatter-resistant film

Questions

Attachment J

ATC-58 Mini-Workshop/Invited Meeting on the Identification of Nonstructural Components of Significance
August 25, 2005

Taxonomy - Nonstructural Components Identifed as Significant in Casualties, Dollar Loss, or Downtime
Reference - NISTIR 6389 (modified)

Key to symbols:		
	●	**Significant**
	◘	**Moderately Significant**
	"Blank"	**Not Significant**

Level 1	Level 2	Level 3	Level 4	Significance: Casualties	Significance: Dollar Loss	Significance: Downtime	Comments
B Shell	B10 Superstructure	B1010 Floor Construction	B1015 Exterior Stairs and Fire Escapes	●	●	●	Needs further study to determine whether it should be treated as part of the structure versus a nonstructural component
		B1020 Roof Construction	B1023 Canopies	●	●	●	Needs further study to determine whether it should be treated as part of the structure versus a nonstructural component
	B20 Ext. Enclosure	B2010 Exterior Walls	B2011 Exterior Wall Construction	●	●	●	
			B2012 Parapets	●	●	●	Dollar loss may be insignificant
			B2016 Exterior Soffits	●	●		Assumes that any cleanup associated with building egress is accomplished in less than one day
			B2020 Ext. Windows	●	●	◘	In some cases broken exterior windows may not significantly impact downtime
			B2022 Curtain Walls	●	●	◘	
			B2030 Exterior Door	◘	●	●	Further study needed to assess impact of damage on safe egress
	B30 Roofing	B3010 Roof Cover	B3017 Tile or Slate Roof	●	●		
		B3020 Roof Openings	B3021 Glazed Roof Openings	●	●		
	B40 Ext. Finishes	B4010 Ext. Finish	B4041 Wall Finishes to Exterior	●	●		Intended to cover brick masonry and stone veneer
C Interiors	C10 Int. Construction	C1010 Partitions	C1011 Fixed Partitions (gypbd and sim)		●	◘	Finish materials need to be addressed in cost of repairs (ceramic tile, e.g.)
			C1011 Fixed Partitions (masonry)	●	●	●	
		C1020 Int. Doors	C1021 Interior Doors		●		Further study needed to assess impact of damage on safe egress
	C20 Stairs	C2010 Interior Stairs		●	●	●	Needs further study to determine whether it should be treated as part of the structure versus a nonstructural component
	C30 Int. Finishes	C3020 Floor Finish	C3027 Access Pedestal Flooring		●	●	
		C3030 Ceiling Finish	C3032 Suspended Ceilings	◘	●	●	Further study needed to determine whether ceiling should be considered as a system (include lights and diffusers, e.g.)
D Services	D10 Conveying	D1010 Elevator		●	◘	●	
		D1020 Escalator		●	◘	●	
	D20 Plumbing	D2020 Domestic Water Distribution			●	●	Note: Benefits/limitation of piping aggregation should be studied
		D2030 Sanitary Waste			●	●	
		D2090 Other Plumbing		●	●	●	Concern for gas distribution, acid waster, etc. Occupancy dependant.

	D30 HVAC	Sam Swan to develop list of HVAC items					NISTIR 6389 Taxonomy not well-suited for performance assessment. Needs further study to develop list of categories.
	D40 Fire Protection	D4010 Sprinklers		◘	●	●	Casualty risk associated with falling hazard judged to be small
		D4020 Standpipe			●	●	Wet side only
	D50 Electrical	Sam Swan to develop list of electrical items					NISTIR 6389 Taxonomy not well-suited for performance assessment. Needs further study to develop list of categories.
		D5020 Lighting	D5022 Lighting Equipment	●	●	●	Study aggregation of lighting with ceiling system, where possible
E Equipment and Furnishings							Occupancy Dependent; Need "on/off switch" since stakeholder may not be concerned with tenant losses
	Office	Desktop Computers			●	●	
		Tall File Cabinets		●	●	●	
		Tall Slender Bookshelves			●	●	
		Business Equipment (printers, etc)			●	●	
	Classrooms	Bookshelves		●	●	●	
		Desktop Computers			●	●	
		Tall File Cabinets		●	●	●	
	Warehouse	Storage Racks		●	●	●	
		Contents on Racks		●	●	●	
	Retail	Storage Racks		●	●	●	
		Tall Display Racks		●	●	●	
		Contents on Racks		●	●	●	
		Cold Room			●	●	
	Hotels/Dorms	Kitchen Equipment			●	●	
	Multi-Family Residential	Desktop Computers			●		
		Home Entertainment Equipment			●		
		China			●		
	Hospitals	Medical Equipment		●	●	●	
		Kitchen Equipment			●	●	
		Tall Bookcases		●	●	●	
		Desktop Computers			●	●	

Earthquake Performance Data from the Electric Power Research Institute (EPRI) Database Relevant to HVAC Systems Serving Residential & Commercial Buildings

Generic Equipment Category & Number of Examples from EPRI Database	Probability of Equipment Damage Requiring Prolonged Repair or Replacement			
	Overall Failure Rate	MMI VII	MMI VIII	MMI IX
Gas-Fired Steam/Hot Water boilers	Sample size: 24 Failures: 2 Overall failure rate = 8%	Sample size too small to allow estimates by shaking intensity		
Packaged Circulating Water Chillers	Sample size: 60 Failures: 1 Overall failure rate = 1 - 2%	½%	2%	7%
Motor-Driven Pumps (horizontal, 10 – 200 horsepower)	Sample size: 270 Failures: 9 Overall failure rate = 3%	½%	2%	10%
Centrifugal Fans (Including spring-mounted with or without seismic design)	Sample size: ~200 Failures: 26 Overall failure rate = 13%	½%	5%	30%
Air Handlers (coils, filters, louvers, fans)	Sample size: 70 Failures: 11 Overall failure rate = 15%	4%	10%	15%
Programmable Controllers (Mounted in free-standing cabinets, anchored or unanchored)	Sample size: 60 Failures: 7 Overall failure rate = 12%	3%	5%	30%
Vertical Steel Tanks (1,000 – 100,000 gallons, anchored or unanchored)	Sample size: 220 Failures: 22 Overall failure rate = 10%	1%	5%	25%
Hot & chilled water piping (per in-building runs of 1,000 feet, excluding failures due to shifting equipment)	Twenty-three E.Q.-induced leaks out of an inventory of ~200 miles of piping (Sample from steam power plants only) Overall failure rate = 2% per 1,000-ft of line	1/10%	3%	20%

Earthquake Performance Data from the EPRI Database Relevant to Electrical Systems Serving Residential & Commercial Buildings

Generic Equipment Category & Number of Examples from EPRI Database	Probability of Equipment Damage Requiring Prolonged Repair or Replacement			
	Overall Failure Rate	MMI VII	MMI VIII	MMI IX
Standby Generators (50 kilowatts – 20 megawatts)	Sample size: 160 Failures: 28 Overall failure rate = 18%	5%	15%	25%
Unit Substation Transformers (Typically 12 kilovolts to 480 volts, 500 – 5,000 kVA)	Sample size: 250 Failures: 7 Overall failure rate = 3%	½%	2%	15%
Medium Voltage Switchgear (Typically 4 – 12 kilovolt)	Sample size: 150 Failures: 5 Overall failure rate = 3%	½%	3%	18%
Low Voltage Switchgear (4800 volt)	Sample size: 120 Failures: 4 Overall failure rate = 3%	½%	3%	18%
Motor Control Centers & Switchboards (240 – 480 volt in free-standing cabinets anchored or unanchored)	Sample size: 270 Failures: 6 Overall failure rate = 2%	½%	1%	4%