U.S. Building Code Seismic Testing Requirements for Nonstructural Components

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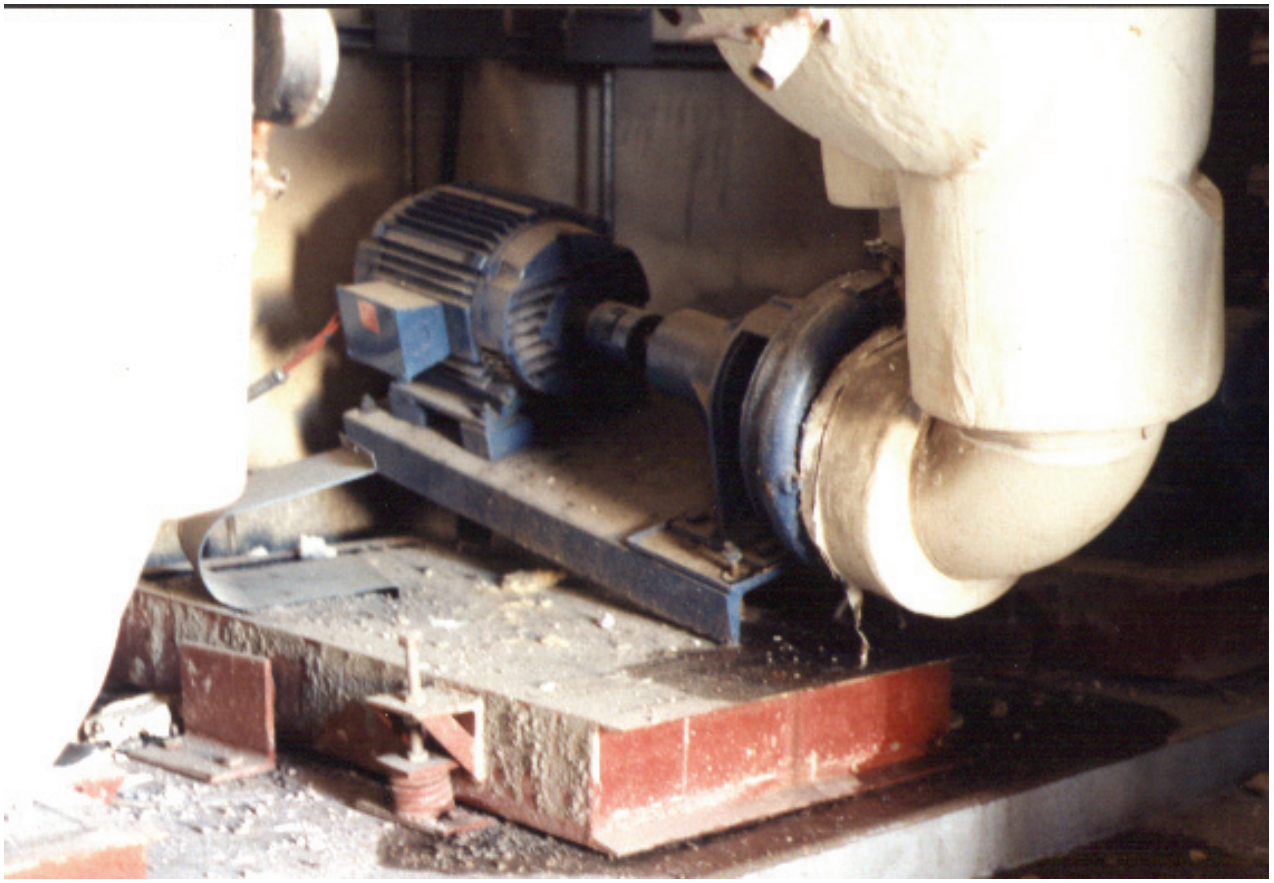
for 2002 and 2005 Editions

Nonstructural Components and Systems

- Architectural components includes cladding, ceilings, glazing, partitions, etc.
- Mechanical and electrical components and systems (utilities)
- Contents including medical equipment, communications equipment, computers, shelves and bookcases, valuable contents on shelves, etc.

Northridge Earthquake



OSHPD/FDD

Northridge Earthquake

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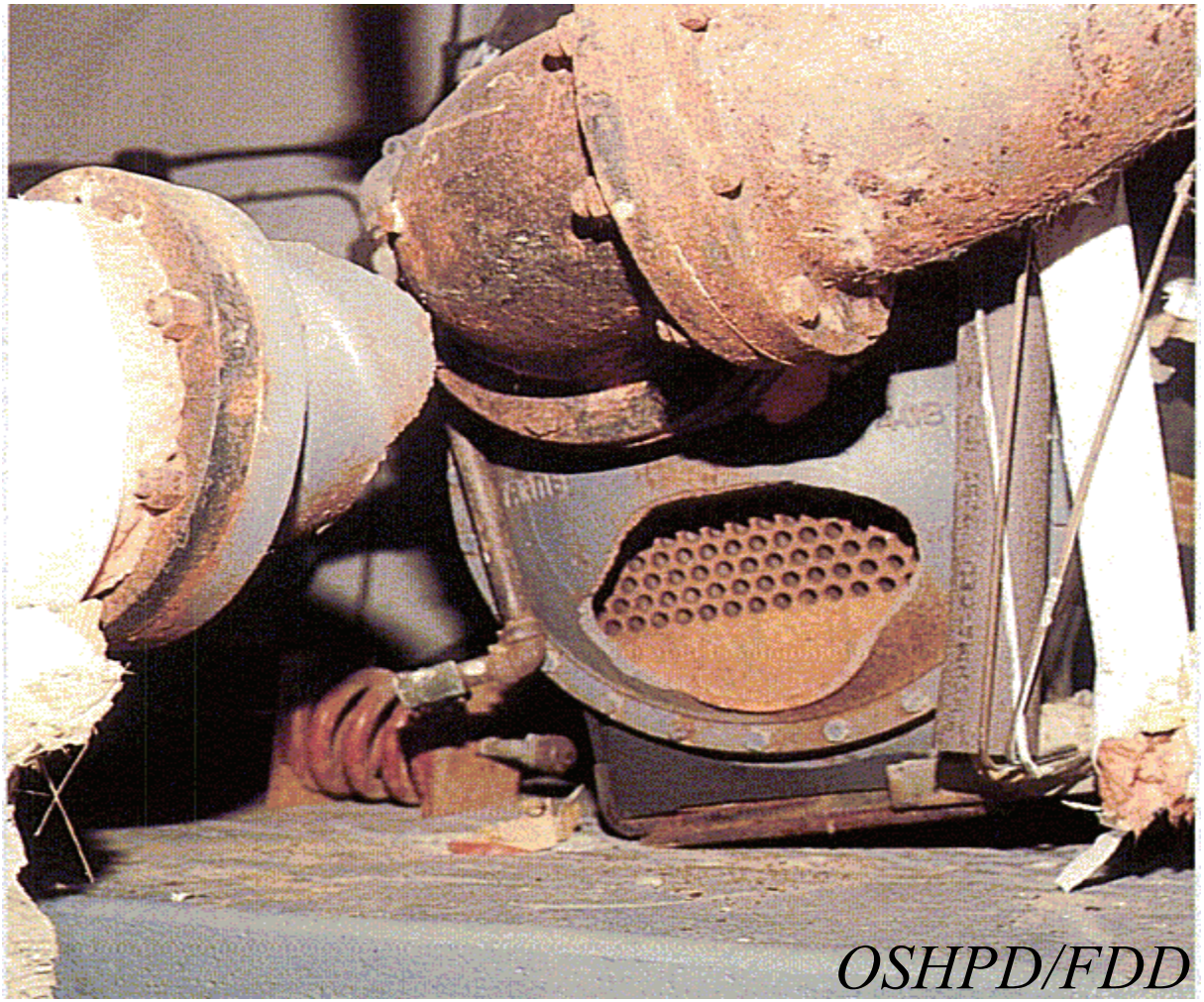
Northridge Earthquake

Pipe Connection to Chiller

The restrained equipment and piping move out of phase during an earthquake and the case shells are not designed to resist the force necessary to drag the piping



OSHPD/FDD

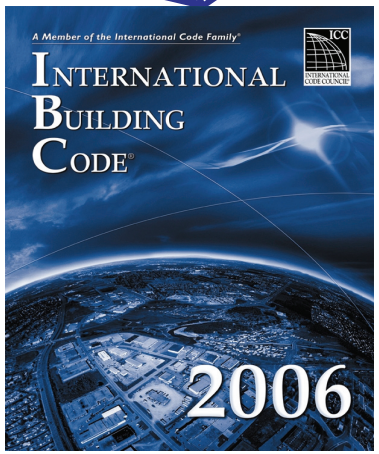
U.S. Building Code Seismic Requirements

National Design Specification

Load & Resistance Factor Design

NFPA INTERNATIONAL

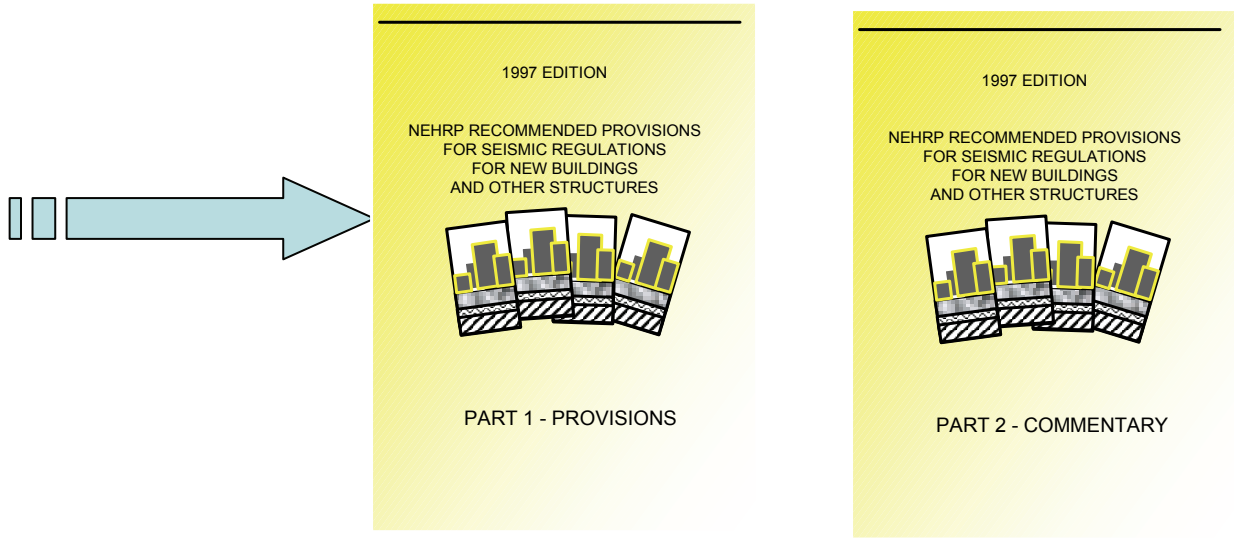
NFPA 5000 Building Code



NEHRP Provisions

ATC 3.06

Tentative Recommended Provisions for Seismic Regulation of Buildings



- First published by BSSC in 1985
- Was updated on 3-year cycle (1988, 91, 94, 97 ,00, 03) – However now on 5 - 6 year cycle
- 1992 - Adopted by BOCA, SBCCI
- 1993 – Adopted by ASCE 7 for Seismic
- 1995 - IBC resolves to adopt as basis for IBC
- 2008 – Adopting ASCE-7-05 as Reference Basis

Key Factors in Seismic Design

- Mapped Ground Motions S_s and S_1
- Site Classification A – F
- Site Response Coefficients F_a and F_v
  - F_a - Nonlinear function of S_s and Site Class
  - F_v - Nonlinear function of S_1 and Site Class
- Design Ground Motion Coefficients

$$S_{DS} = 2/3\ F_a\ S_s$$
$$S_{D1} = 2/3\ F_v\ S_1$$

Other Key Factors
Occupancy Category and Importance Factors

- Occupancy Category I to IV and
- Importance Factor, I_E 1.0 to1.5

	Occ. Cat.	I_E
Low hazard	I	1.0
All Other	II	1.0
Important	III	1.25
Essential	**IV**	**1.50**

Nonstructural Importance Factor - I_p

- Nonstructural Component Importance Factor, I_p , assigned **to all components**
- The values of I_p is either 1.0 or 1.5
- The value of I_p is based on:
  1. Requirements of the component to function after a DBE (such as sprinkler systems), or
  2. The component contains hazardous materials, or
  3. Storage Racks open to general public, or
  4. Occupancy Category of the structure or facility
- Nonstructural components/systems which are assigned an I_p = 1.5 are called *Designated Seismic Systems*.

Seismic Design Category

- Assigned to every structure
- Seismic Design Categories A- F

  Function of :

  - Design Ground Motion Values S_{DS} and S_{D1}
  - Occupancy Category

* Important Factor – Decides detailing and exemptions

Nonstructural Limits of Applicability

- Nonstructural provisions apply throughout the US with following exceptions:
  1. Mechanical and Electrical Components in SDC A and B
  2. Mechanical and Electrical in SDC if $I_p = 1.0$
  3. Architectural in SDC A
  4. Architectural in SDC B if $I_p = 1.0$ except for parapets supported by bearing or shear walls
- Other exceptions for light items, piping and ductwork in both

Nonstructural Seismic Demands

- Equivalent Static Forces – F_p Equation – Independent of building structural properties
  1. Strength Level Forces
  2. ASCE 7-05 provides option for determining building specific forces
- Relative Displacements for Selected Components
  1. Anticipated Relative Displacements at Design Earthquake Level (D_p)
  2. Provides explicit equations and option of determining demands using building structural properties

Nonstructural Force Demand

- ASCE 7-05 – Based on 2003 NEHRP

$$F_p = \frac{0.4\, a_p\, S_{DS}}{(R_p / I_p)} \left(1 + 2\frac{z}{h}\right) W_p$$

$$F_p(\text{min}) = 0.3\, S_{DS}\, I_p\, W_p \quad \text{for } S_{DS} = 1.00,\ F_p = 0.30\, I_p W_p$$

$$F_p(\text{max}) = 1.6\, S_{DS}\, I_p\, W_p \quad \text{for } S_{DS} = 1.00,\ F_p = 1.60\, I_p W_p$$

- F_p forces are used to design anchorage and bracing
- For I_p = 1.5 , F_p forces are used to design nonstructural component itself our alternate methods are used to seismically qualify component

Design and Detailing Requirements of Architectural Components

- In 2006 IBC/ASACE 7-05
  1. Specific demands exterior walls and connections
  2. Suspending Ceilings – CISCA & ASTM standards
  3. Glazing – Drift capacity AAMA 501.6
  4. Access Floors – special access floor details
  5. Tall Partitions – independent bracing

Design and Detail Requirements for Mechanical and Electrical Equipment

- In 2006 IBC/ASCE 7-05
  1. Sprinkler systems – NFPA 13 with amendments
  2. Escalators and Elevators – ASME A17.1
  3. Vessels – ASME B& PV
  4. Piping – ASCE B 31.1 & NFPA-13
  5. HVAC Ducting – (SMACNA not specifically referenced)
  6. Lighting fixtures – Prescriptive detail requirements
  7. Many specific prescriptive details for Mechanical and Electrical Equipment – Section 13.6.5.5

Special Certification Requirements for Certain Designated Seismic Systems (I_p=1.5)

- In Chapter 13 of ASCE 7-05 - Seismic qualification required for
  1. Active mechanical and electrical equipment that are required to function following a DBE
  2. Components containing hazardous contents
- Qualification to demonstrate functionality after being subject to a DBE to be determined by either:
  1. Shake table testing – ICC-ES AC-156 , 2004 (latest 2007)
  2. Experience Data
  3. Analysis (extremely difficult for active equipment)
- Certification required by supplier indicating compliance
- Chapter 13 also permits nonstructural components to be optionally seismically qualified by testing or experience data

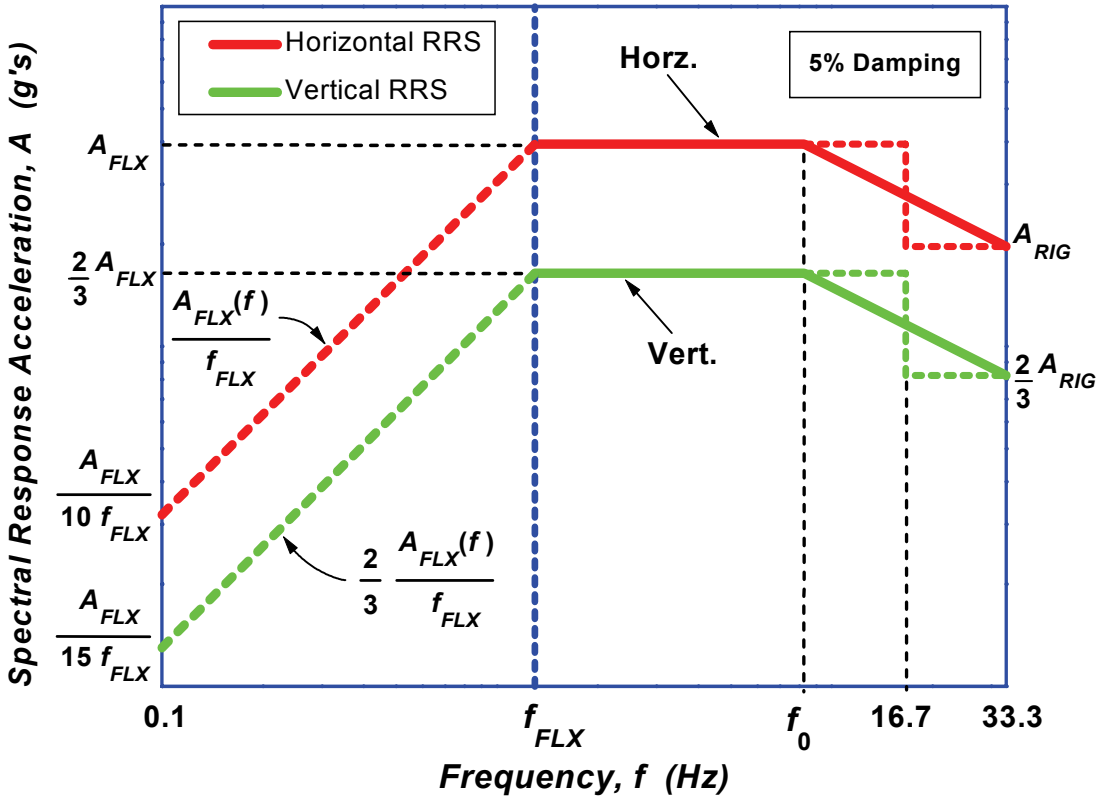
AC-156
Seismic Qualification by Shake Table Testing of Nonstructural Components

- Companion Document to 2006 IBC/ASCE 7-05
- Acceptance Criteria published by ICC Evaluation Services
- First published in 2000, latest version 2007
- Provides testing protocol and test spectra definition
- Test Spectra is tied directly to F_p force equation
- Acceptance Criteria tied to I_p factor. For I_p = 1.5, item much function following test

AC-156 TEST SPECTRA

At Roof (max) $A_{FLX} = 1.6\ S_{DS}$ *and* $A_{RIG} = 1.2\ S_{DS}$

At Ground $A_{FLX} = S_{DS}$ *and* $A_{RIG} = 0.4\ S_{DS}$



Product Specific Certification Criteria Under Development

- Ceiling Systems – ASTM A 580
- HVAC Equipment - ARI
- Expect others soon
- Need to develop formal experience data certification criteria

Other Seismic Testing Specified in 2006 IBC/ASCE 7-05

- Glazing – AAMA 501.6 – *Recommended Dynamic Test Method for Determining Seismic Drift Causing Glass Fallout form a Wall System, 2001*
- Anchorage
  - ACI 355.2 *Evaluating the Performance of Post- Installed Mechanical Anchors in Concrete and Commentary, 2001*
  - ICC ES 193 *Mechanical Anchors in Concrete Elements*
  - ICC ES 308 *Post-installed Adhesive Anchors in Concrete Elements*

Steel Storage Racks

- Not Really a Nonstructural Component
- Connection Testing

  RMI – *Specification for the Design, Testing, Utilization of Industrial Steel Storage Racks, 2007*

Final Comments About the New UB Nonstructural Components Simulator

- Will provide an unprecedented capability to test nonstructural components that are both acceleration and drift sensitive with full scale floor motions
- Will also be able gain a better understanding of the behavior of loose contents which are likely sensitive to large velocities and displacements
- We will need to develop code test protocols that are associated with the capabilities of the new simulator