Building Code Seismic Testing Requirements for Nonstructural Components

CBC Seismic Requirements for Equipment
NEHRP Provisions

• 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
  – 2006 - Adopting ASCE-7-05 as Reference Basis

ATC 3.06 the Next Generation Building Code of the 70’s

Occupancy Category and Importance Factors

• Occupancy Category I to IV and
• Importance Factor, \( I_E = 1.0 \) to 1.5

<table>
<thead>
<tr>
<th>Occ. Cat.</th>
<th>( I_E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Hazard</td>
<td>I</td>
</tr>
<tr>
<td>All Other</td>
<td>II</td>
</tr>
<tr>
<td>Important</td>
<td>III</td>
</tr>
<tr>
<td>Essential</td>
<td>IV</td>
</tr>
</tbody>
</table>
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:
  - Requirements of the component to function after a DBE (such as sprinkler systems), or
  - The component contains hazardous materials, or
  - Storage Racks open to general public; or,
  - The component is in or attached to an Occupancy Category IV structure
- Nonstructural components/systems which are assigned an $I_p = 1.5$ are called “Designated Seismic Systems”.

Seismic Qualification Requirements for Certain “Designated Seismic Systems”

Chapter 13 of ASCE 7-05

- Seismic qualification required for Designated Seismic Systems assigned to Seismic Design Categories C through F as follows:
  - Active mechanical and electrical equipment that are required to function following the DBE
  - Components containing hazardous contents
Drivers of Change - Earthquake Lessons Learned

Seismic Performance of Nonstructural Components

• Damage to nonstructural components can result in:
  – Significant economic losses
    • Cost of building contents exceeds building cost
  – Temporary partial/total loss of operation/functionality (downtime)
  – Injuries
  – Loss of Life
• Past emphasis: Life safety only
• Present: Performance Based
Typical Investment in Building Construction

![Bar chart showing typical investment in building construction for different types of buildings (Office, Hotel, Hospital) for contents, nonstructural, and structural damage.]

Northridge Earthquake

| Performance of all Buildings at 23 Hospital Sites with One or More Yellow or Red Tagged Buildings |
|--------------------------------------------------|----------------------------------|-------------------------------|
| Type of Damage                                   | Pre Act (Number, %)              | Post Act (Number, %)          |
| Structural Damage                                |                                  |                               |
| Red tagged                                       | 12 (24%)                        | 0 (0%)                        |
| Yellow tagged                                    | 17 (33%)                        | 1 (3%)                        |
| Green tagged                                     | 22 (43%)                        | 30 (97%)                      |
| Nonstructural Damage                             |                                  |                               |
| Major                                            | 31 (61%)                        | 7 (23%)                       |
| Minor                                            | 20 (39%)                        | 24 (77%)                      |
| Total Buildings                                  | 51                               | 31                             |
Pre CBC-07 Seismic Qualification Requirements

9.6.3.6 Component Certification
The manufacturer's certificate of compliance with the force requirements of the Section shall be submitted to the regulatory agency when required by the contract documents or when required by the regulatory agency.

IBC 2000

1707.7.2 Component and attachment testing. The component manufacturer shall test or analyze the component and the component mounting system or anchorage for the design forces in Chapter 16 for those components having a Component Importance Factor of 1.0 or 1.5 in accordance with Chapter 16. The manufacturer shall submit a certificate of compliance for review and acceptance by the registered design professional responsible for the design, and for approval by the building official. The basis of certification shall be by test on a shaking table, by three-dimensional shock tests, by an analytical method using dynamic characteristics and forces from Chapter 16 or by more rigorous analysis. The special inspector shall inspect the component and verify that the label, anchorage or mounting conforms to the certificate of compliance.
Pre CBC-07 Seismic Qualification Requirements

ASCE 7-02

Seismic Qualification Requirements for Certain Designated Seismic Systems

- Qualification to demonstrate functionality after being subject to a DBE to be determined by either:
  - Shake table testing
  - Experience Data
  - Analysis (extremely difficult for active equipment)
- Certification required by supplier indicating compliance
Seismic Qualification by Analysis

Post Shake Table Test (Multiple)

Photo by: Philip Caldwell
Seismic Qualification by Testing

Seismic Qualification by Experience Data
Seismic Qualification by Experience Data

- Requirements for qualification basis
  - Database of equipment categories
    - Subjected to known strong motion event
    - Detailed engineering studies of performance
    - Anchorage evaluation
    - Root cause of failure determined by experts
  - Project site lower demand than database
  - Equipment must be of equal or better construction

Overview of Qualification Standards

- IEEE 344 – Safety related equipment qualification
- Not building code based
  - Different expectations
  - Linear-elastic performance
  - Operational through event
- Used as basis for other seismic standards
  - IEEE 693
  - Telcordia GR-63
  - ICC ES AC156
Overview of Qualification Standards

• Telcordia GR-63 – Telephone Network Equipment
  – Targeted at telephone central office equipment
  – Seismic is only one of many GR-63 requirements
  – Not building code based

Photo by: Philip Caldwell

Overview of Qualification Standards

• Prior to 2000 - No standard, ad-hoc testing protocol by labs

![Comparison of RRS Requirement by Two Different Labs for Same Qualification](image-url)
Solution for Building Code Qualification Testing

• Prior to 2000 – No standard, ad-hoc testing protocol by labs

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

Transform

Code Intent Missing

Shake table test
dynamic demand

Code basis is static
lateral push over force

Solution for Building Code Qualification Testing

• Building code based test protocol needs
  – Based on site specific design parameters

Excerpt of Figure 3.3-3 from FEMA 450 Part 1 (2003 NEHRP Provisions) L.A. area -MCE ground motion 0.2 sec spectral response acceleration (5% critical damping), site class B
Solution for Building Code Qualification Testing

• Time history that envelopes a wide range of earthquakes

Shake Table Test Motion

Solution for Building Code Qualification Testing

• Protocol accounts for above grade installation
  – Independent of building/structure type

Olive View Hospital M. C., 1994 Northridge Earthquake
Solution for Building Code Qualification Testing

• Building code based needs
  – Consistent and conservative dynamic test

Solution for Building Code Qualification Testing

• Acceptance Criteria
  – Account for post event pass/fail criteria
    • Post event functionality for critical facilities
Solution for Building Code Qualification Testing

• Account for post event pass/fail criteria
  – Ip= 1.5 Post test functionality verified

Solution for Building Code Qualification Testing

• Protocol by national body of subject matter experts
  – Academia
  – Practice
  – Industry
  – Test facilities
Solution for Building Code Qualification Testing

• ICC ES AC156 now referenced in ASCE/SEI 7-05

13.2.5 Testing Alternative for Seismic Capacity Determination. As an alternative to the analytical requirements of Sections 13.2 through 13.6, testing shall be deemed as an acceptable method to determine the seismic capacity of components and their supports and attachments. Seismic qualification by testing based upon a nationally recognized testing standard procedure, such as ICC-ES AC 156, acceptable to the authority having jurisdiction shall be deemed to satisfy the design and evaluation requirements provided that the substantiated seismic capacities equal or exceed the seismic demands determined in accordance with Sections 13.3.1 and 13.3.2.

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 $I_p = 1.5$, Equipment to remain functional following the 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
Other Seismic Testing Specified in 2006 IBC/ASCE 7-05


- **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

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2007 Code Adoption Calendar

![Calendar Image]
## OSHPD CANS and PINS

### POLICY INTENT NOTICE (PIN) INDEX

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<th>DATE FIRST ISSUED</th>
<th>DATE REvised</th>
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<td>Special Seismic Certification Deferred Submittal</td>
<td>7/1/08</td>
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<td>(rescinded - see CAN 2-1708A.5)</td>
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Progress Today

• Several 100’s of equipment qualified
• Several Testing facilities Available
• Available lists of tested equipment
  – OSHPD
  – Others