Special Seismic Certification

March 26, 2010

Office of
Statewide Health Planning and Development oshpd

Facilities Development Division

The Building Department for California's Hospitals

Presentation by M. R. Karim
For IEEE San Francisco Section
At Marriott Pleasanton

Nick Names

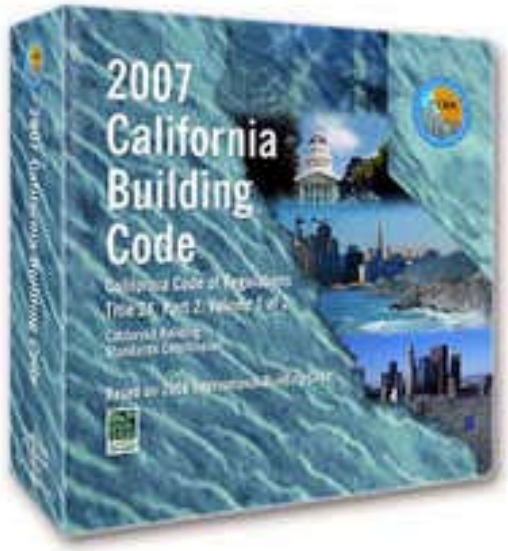
Special Seismic Certification is Also Known As (AKA):

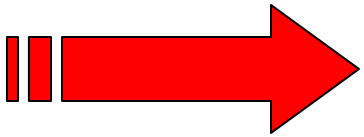
- **Seismic Qualification** of Equipment and Components

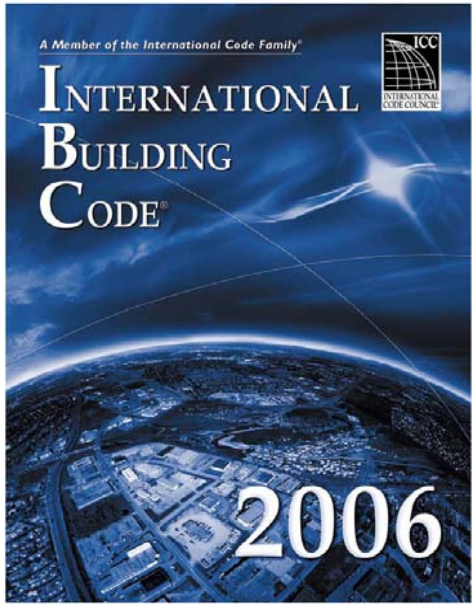
(IBC 2006 Section 1708.5 and CBC 2007 Section 1708A.5)

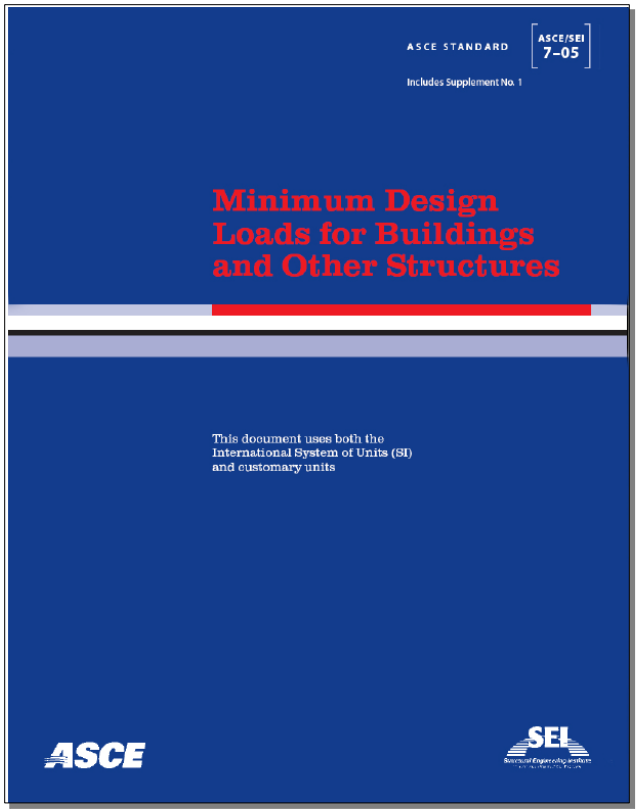
- **Special Certification** for Designated Seismic System (ASCE 7-05 Section 13.2.2)

Codes and Standards Relationship









What is Designated Seismic System?

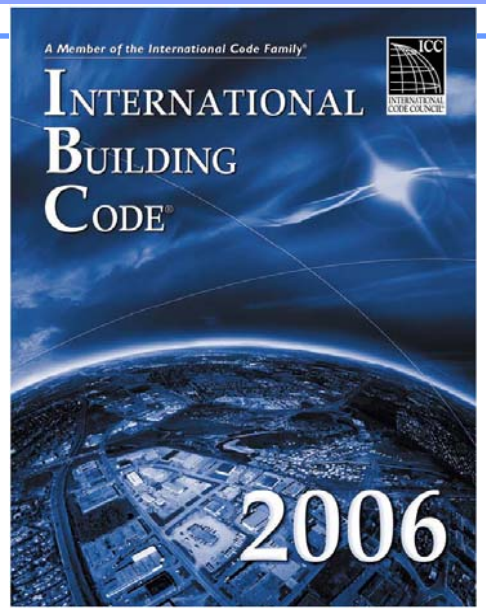
•Any Component or System with Importance Factor (I_p) is Greater than 1.0 is called Designated Seismic System (CBC 2007 Section 1702A)

Nonstructural Component Importance Factor

- Component Importance (I_p) is either 1.0 or 1.5 (ASCE 7-05 Section 13.1.3)

- Component Importance (I_p) is 1.5 if:
  - Component is required to function for life-safety
  - Component contains hazardous materials
  - Components is in essential facilities and its failure could impair the continued operation of the facility

Intent of Building Code



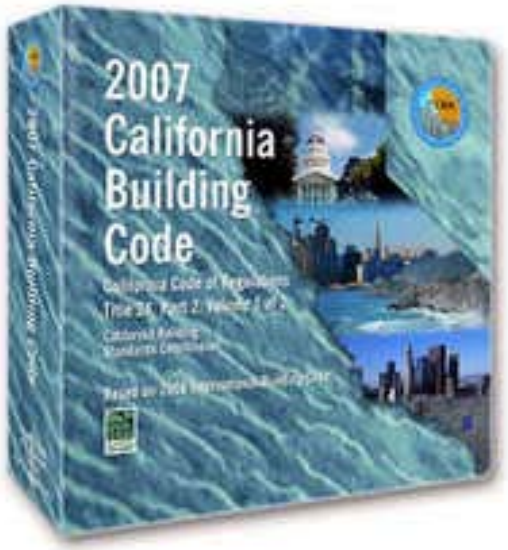
Provide reasonable assurance of seismic performance that will:

1. Avoid serious injury and life loss,
2. **Avoid loss of function in critical facilities,**
3. Minimize structural and nonstructural repair costs where practical to do so.

Statutory Mandate for OSHPD

HOSPITAL FACILITIES
SEISMIC SAFETY ACT 1983 (HSSA 83)

•Hospital buildings that house patients who have less than the capacity of normally healthy persons to protect themselves… must be reasonably capable of providing services to the public after a disaster



Seismic Performance of Nonstructural Components

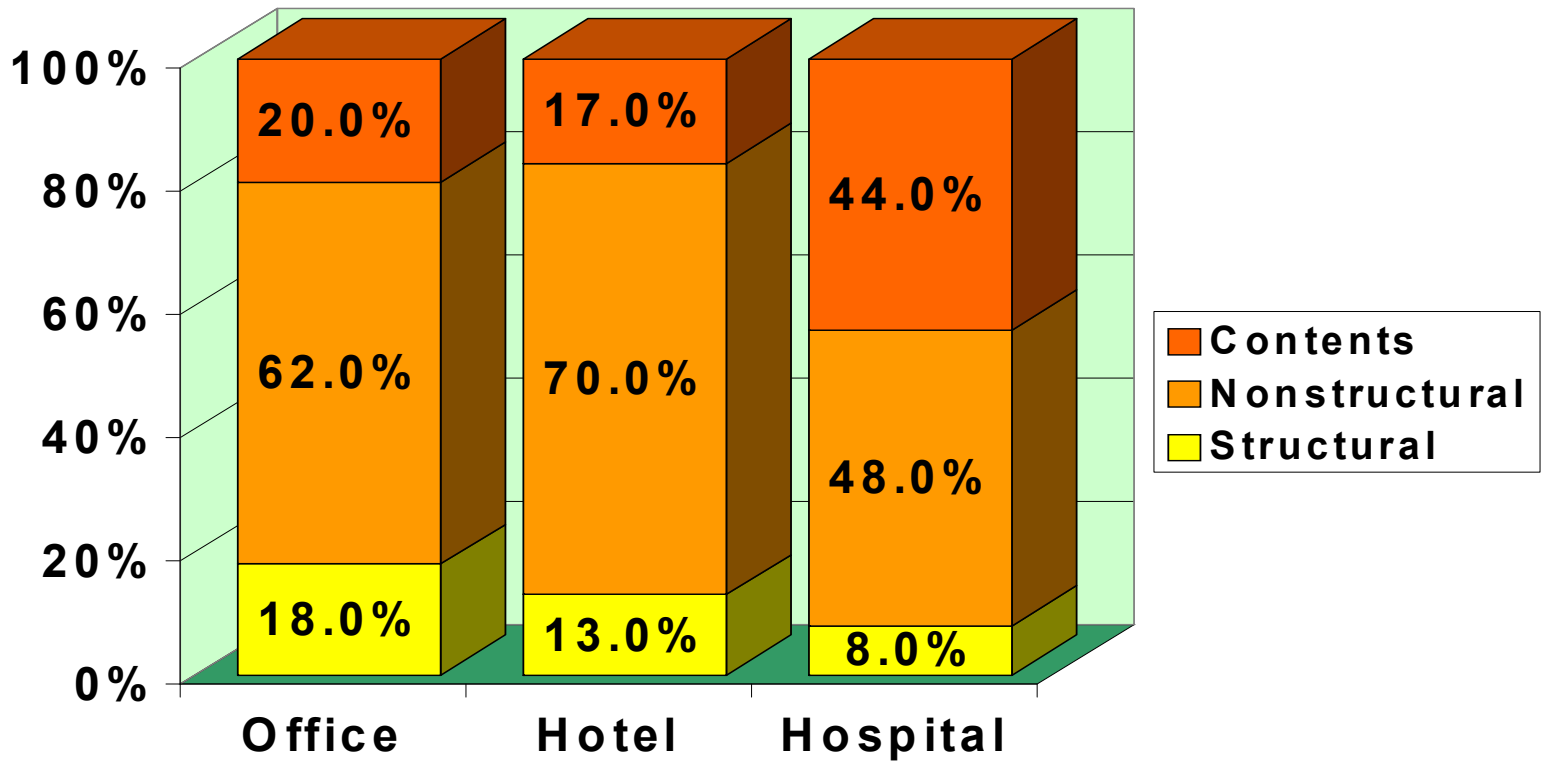
•Damage to nonstructural components can result in:

- Significant economic losses
- **Cost of building contents exceeds building cost**
- Temporary partial/total loss of operation/functionality
- Injuries and Loss of Life

•Past Emphasis: Life safety and Position Retention only

•Present Focus: Maintaining Functionality

Capital Investment in Modern Building

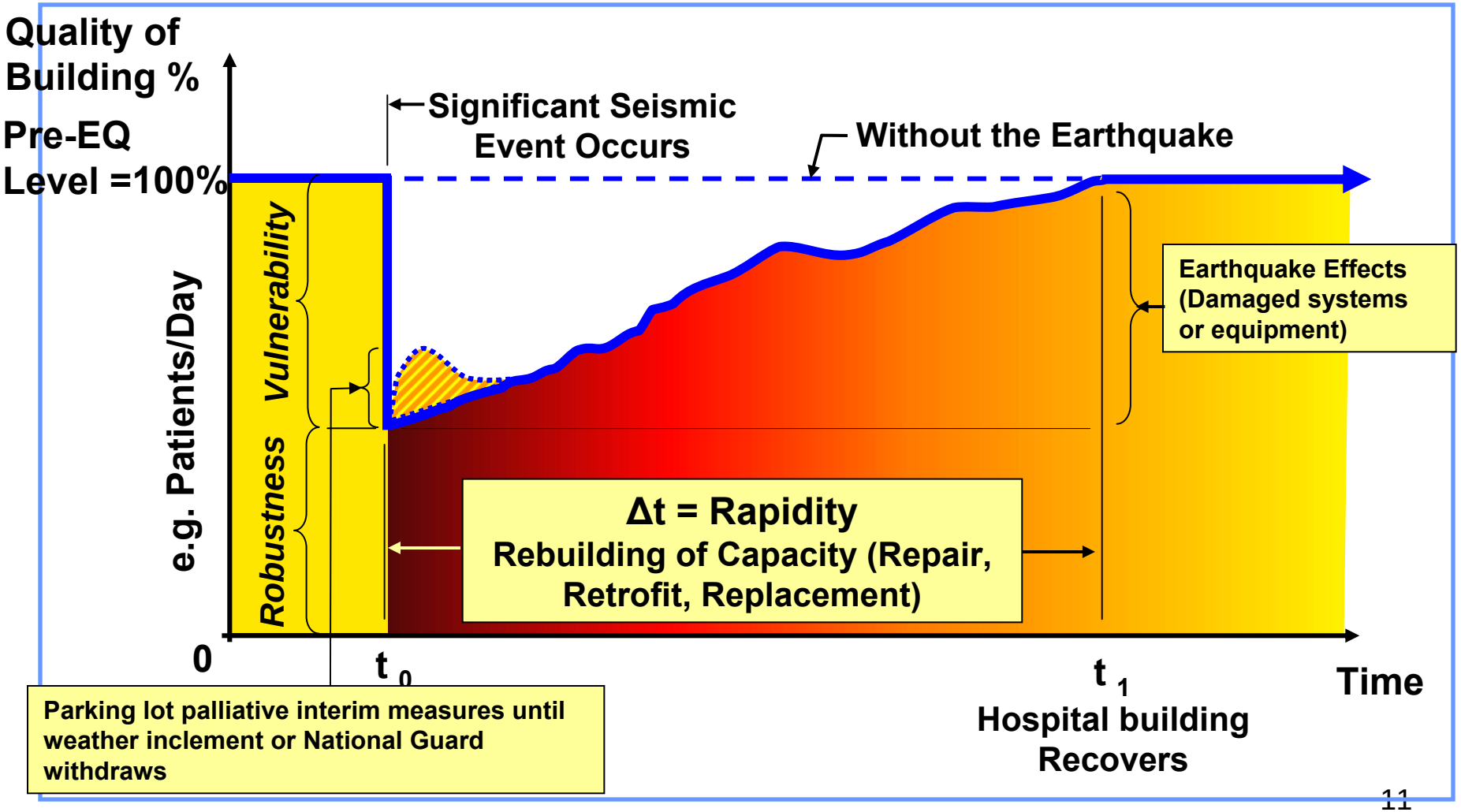


E. Miranda, 2003

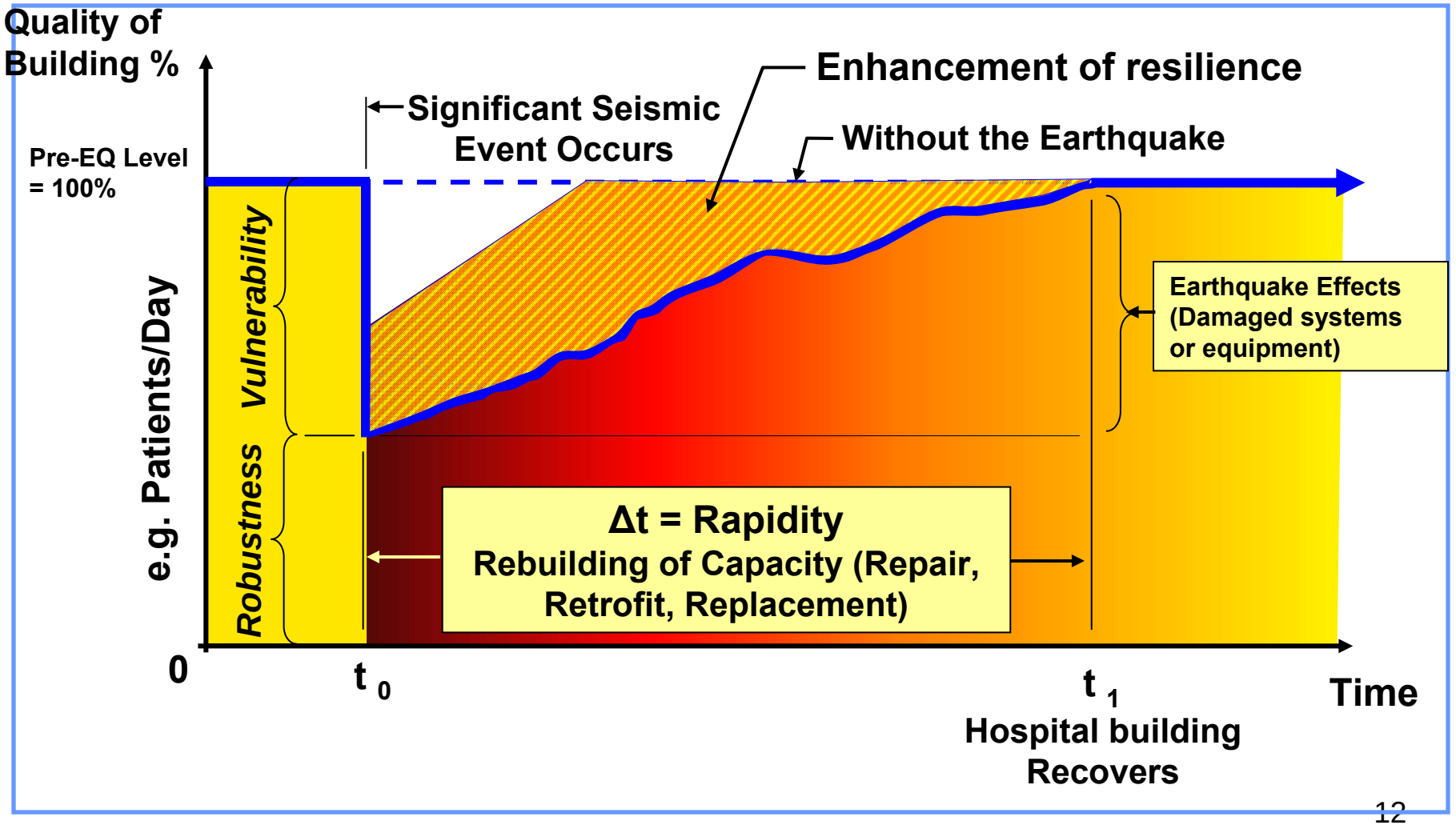
Northridge Earthquake

Performance of all Buildings at 23 Hospital Sites with One or More Yellow or Red Tagged Buildings		
	Number (%) of Buildings	
Type of Damage	Pre-1973	Post-1973
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

Quantification of Seismic Resilience for a Critical Facility

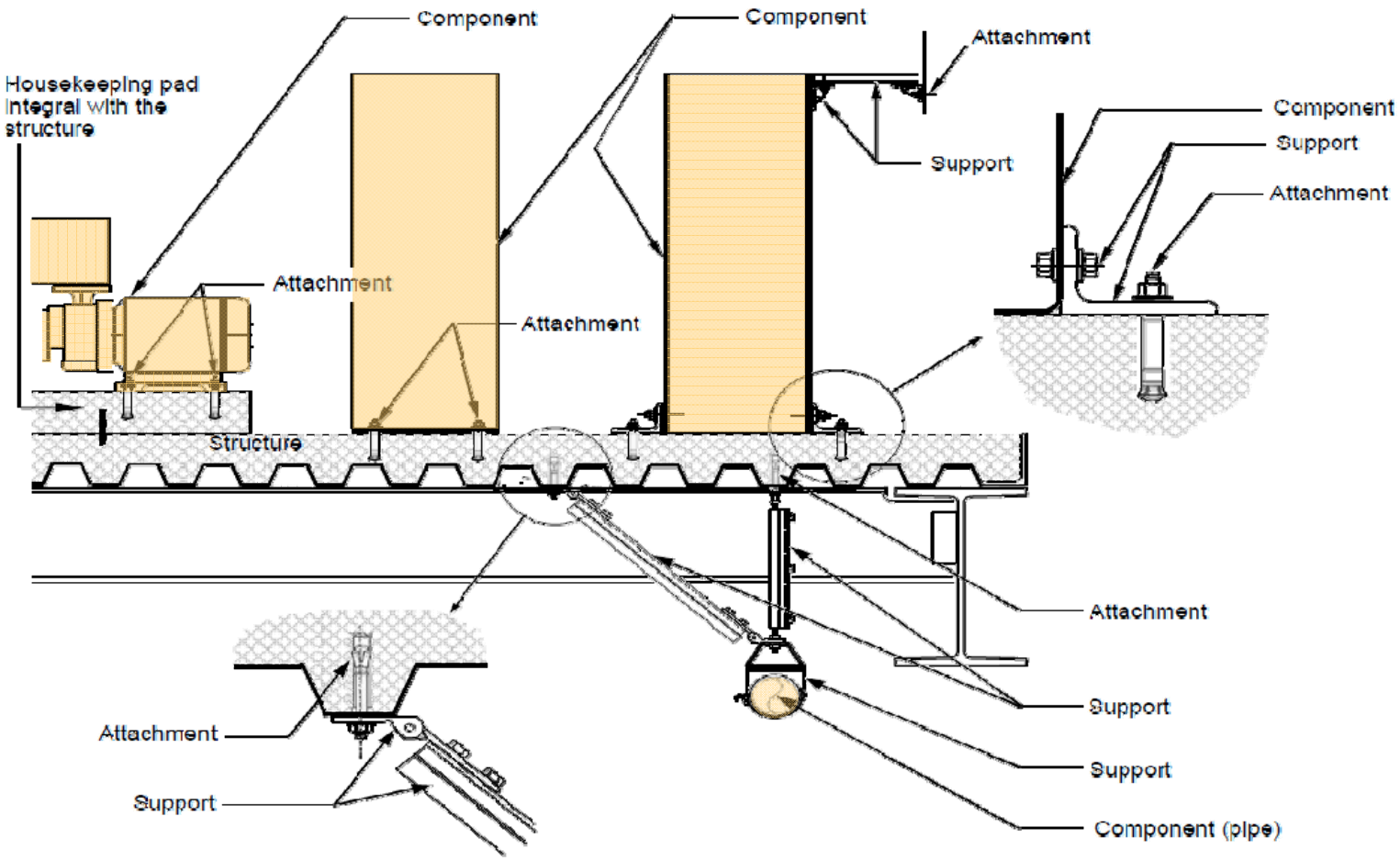


Enhancement of Seismic Resilience for a Critical Facility



Drivers of Change
Earthquake Lessons Learned

What are Components, Supports, and Attachments?



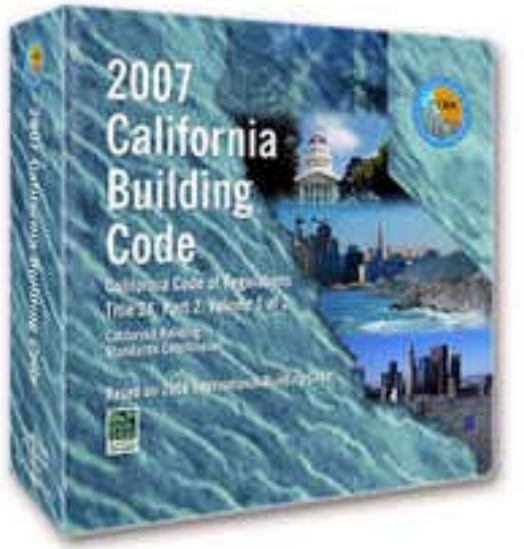
Special Certification for Certain “Designated Seismic Systems”

Section 13.2.2 of ASCE 7-05

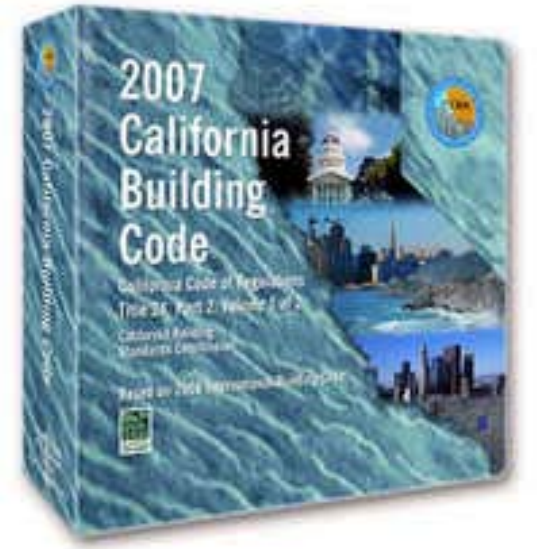
- Special Certification is required for **Designated Seismic Systems assigned to Seismic Design Categories C through F** as follows:
  - **Active** mechanical and electrical equipment that are **required to function** following the Design Earthquake
  - Components containing hazardous contents

CBC 2007 Section 1708A.5: Seismic qualification of mechanical and electrical equipment

- The **registered design professional in responsible charge shall state the applicable seismic qualification requirements** for designated seismic systems on the construction documents.
- **Each manufacturer of designated seismic system components shall test or analyze the component and its mounting system or anchorage and submit a certificate of compliance** for review and acceptance by the registered design professional in responsible charge of the design of the designated seismic system and for approval by the building official.
- **Qualification shall be by an actual test on a shake table**, by three dimensional shock tests, by an analytical method using dynamic characteristics and forces, by the use of experience data (i.e., historical data demonstrating acceptable seismic performance) or by a more rigorous analysis providing for equivalent safety.

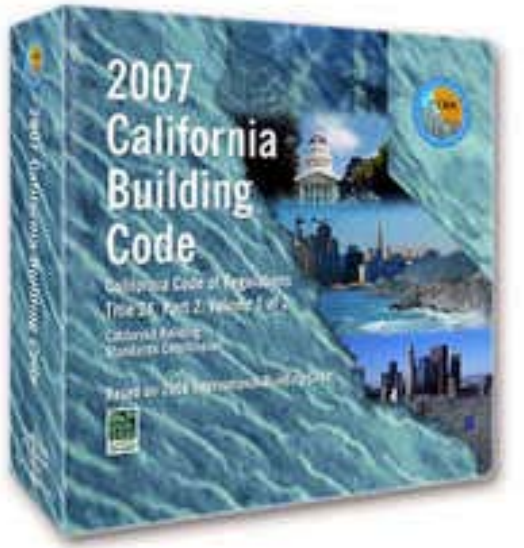


Seismic qualification of mechanical and electrical equipment



- Qualification to demonstrate functionality after being subject to a **Design Earthquake** to be determined by either:
  - **Shake table testing**
  - Experience Data
  - Analysis (Active and Energized Components must be qualified by shake table test)
  - More rigorous analysis providing for equivalent safety

Active and Rugged equipment



- **Active Equipment.** Equipment containing moving or rotating parts, electrical parts such as switches or relays, or other internal components that are sensitive to earthquake forces and critical to the function of the equipment.

- **Rugged Equipment.** Rugged equipment refers to an ampleness of construction that gives such equipment the ability to survive earthquake strong motions without significant loss of function.

- **Significant Loss of Function.** Significant loss of function for equipment or components means the equipment or component cannot be restored to its original function by competent technicians after a design earthquake because the equipment or component require parts that are not normally stocked by the hospital or not readily available.

Seismic Qualification by Analysis

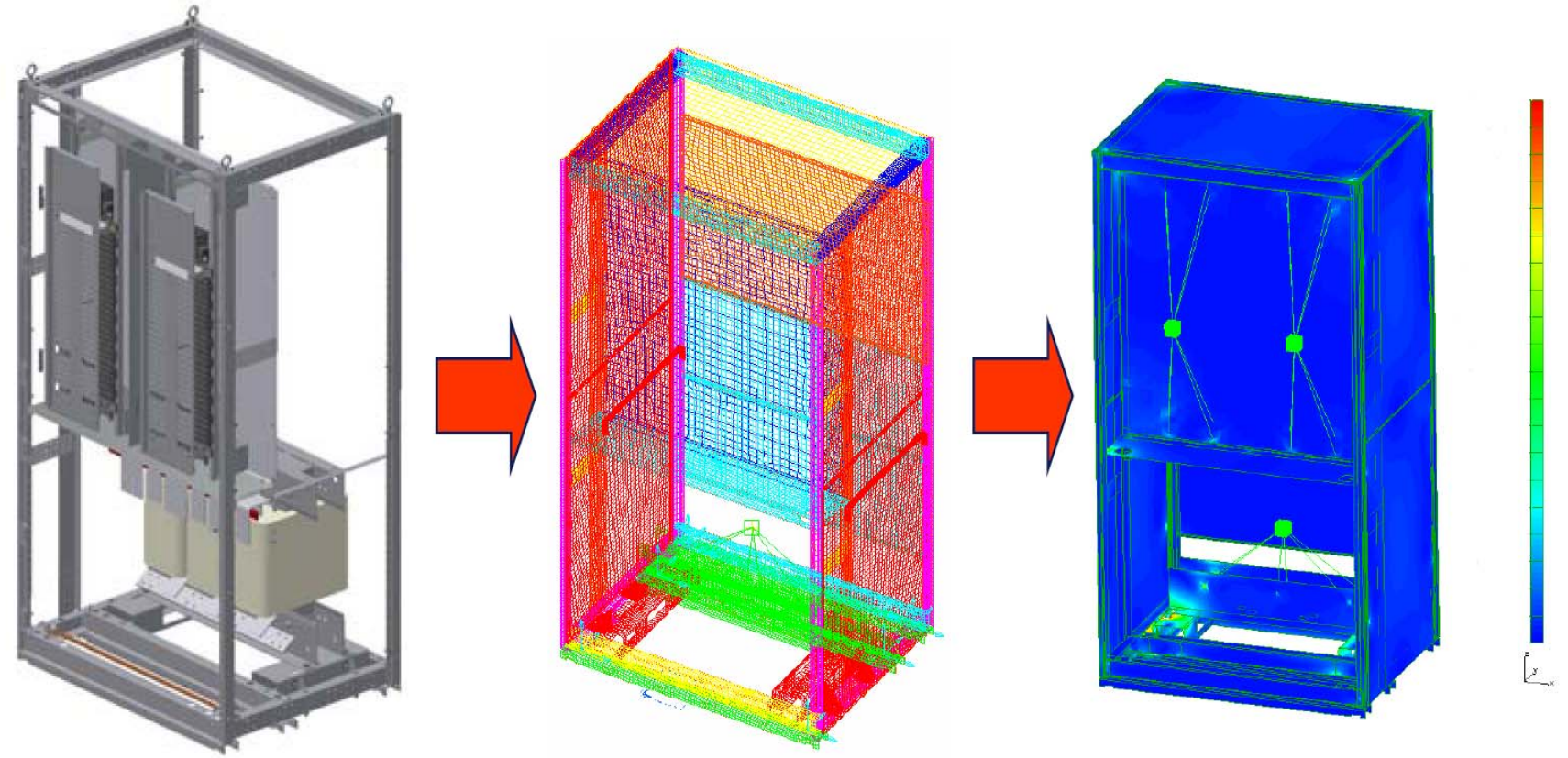


Illustration by Schneider Electric

Seismic Qualification by Testing

Demand In Accordance with ASCE 7-05

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

Amplification Factor

Component Response Factor

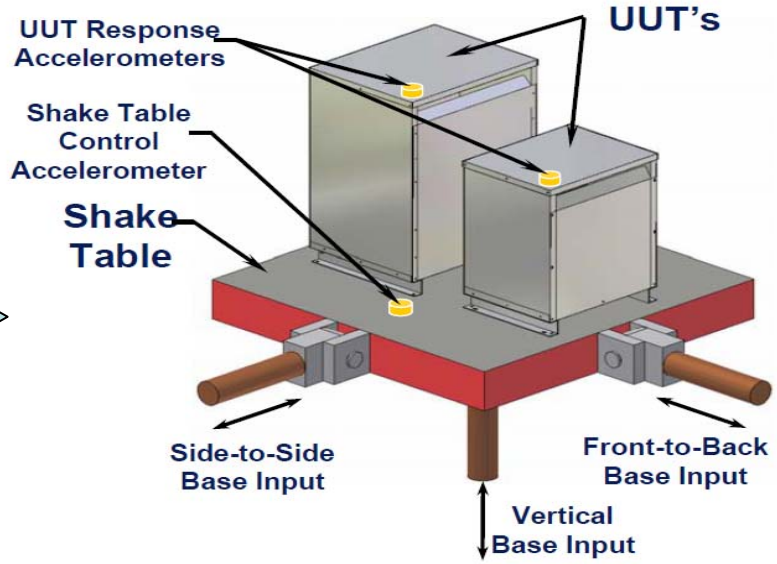
Amplification over height of structure

Translating Building Code Requirement to Test Protocol

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

Building Code Design Seismic Force on Non-Structural Components (Static Demand)

Transform



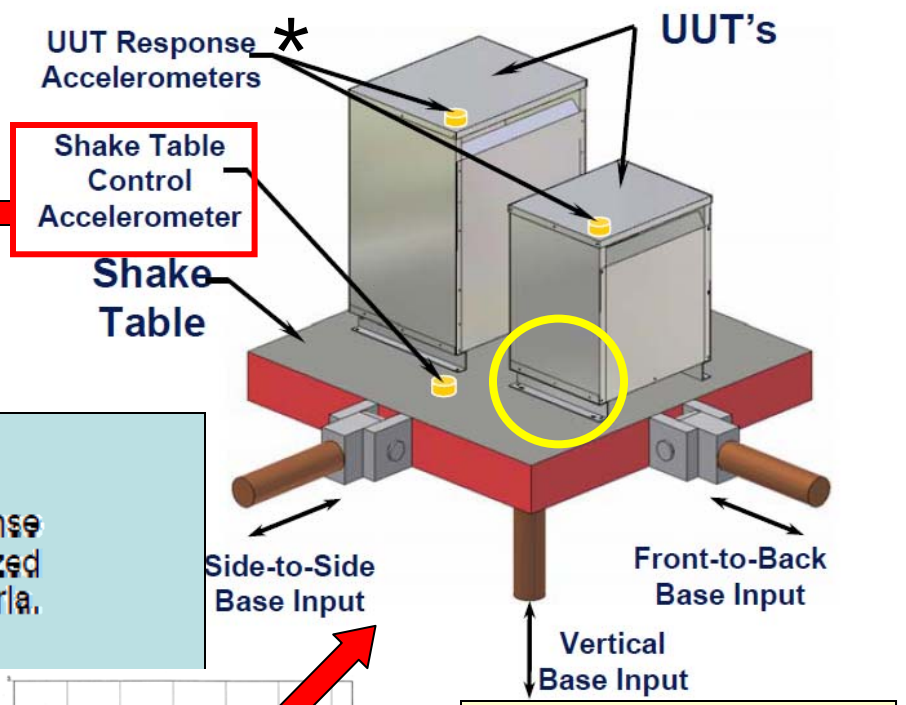
Shake Table Test Dynamic Demand

Illustration by Jeff Gatscher & Scott Littler

ICC-ES AC 156 Shake Table Test Criteria

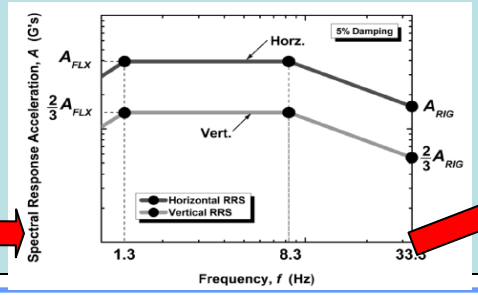
3.13 Test Response Spectrum (TRS): The acceleration response spectrum that is developed from the actual time history of the motion of the shake table test.

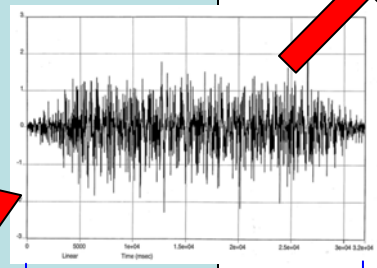
6.5.3 Test Response Spectrum Analysis: The test response spectrum (TRS) shall be computed using either justifiable analytical techniques or response spectrum analysis equipment using the control accelerometers located at the UUT base per Section 6.4.3. The TRS shall be calculated using a damping value equal to 5 percent of critical damping. The TRS must envelop the RRS based on a maximum-one-sixth octave bandwidth resolution over the frequency range from 1.3 to 33.3 Hz, or up to the shake



3.10 Required Response Spectrum (RRS): The response spectrum generated using the formulas and normalized spectra detailed in Section 6.6.1 of this acceptance criteria. The RRS constitutes a requirement to be met.

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



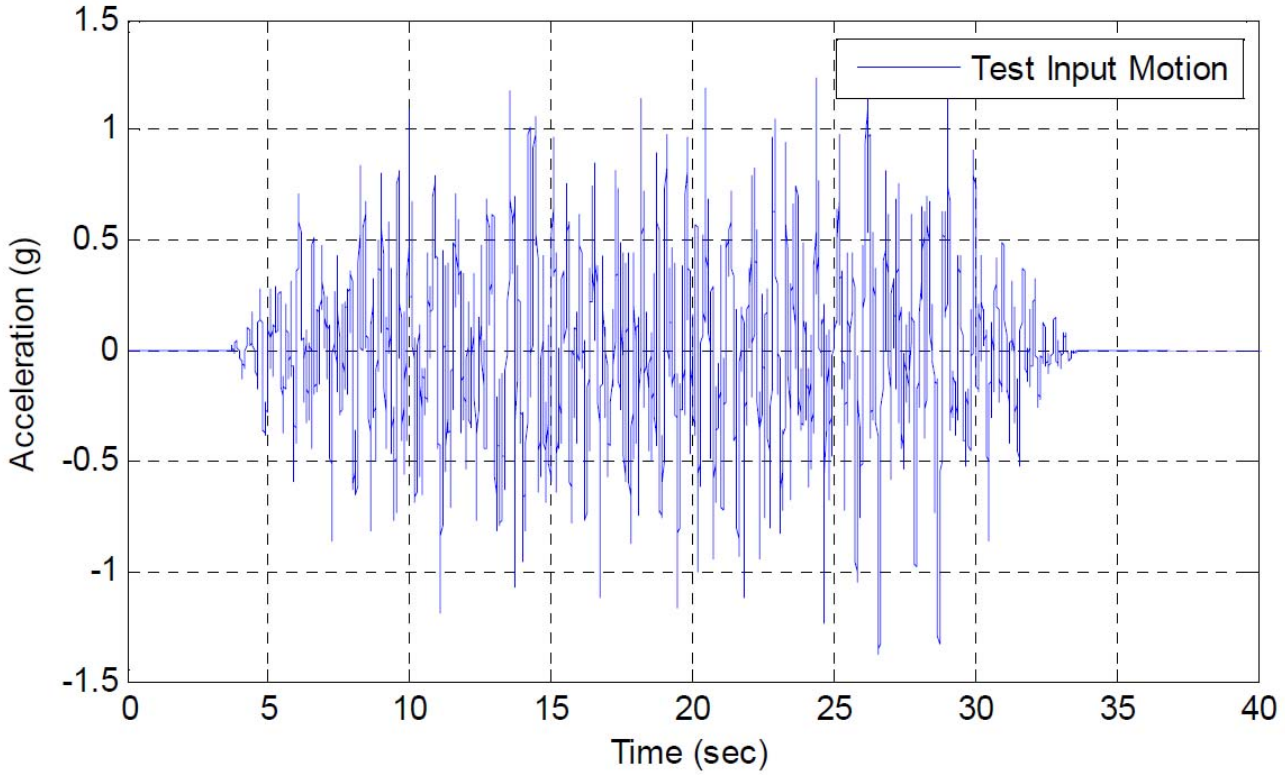


30 Seconds

***UUT response Accelerometers to be Used to Capture Component Response i.e. Resonant frequency etc.**

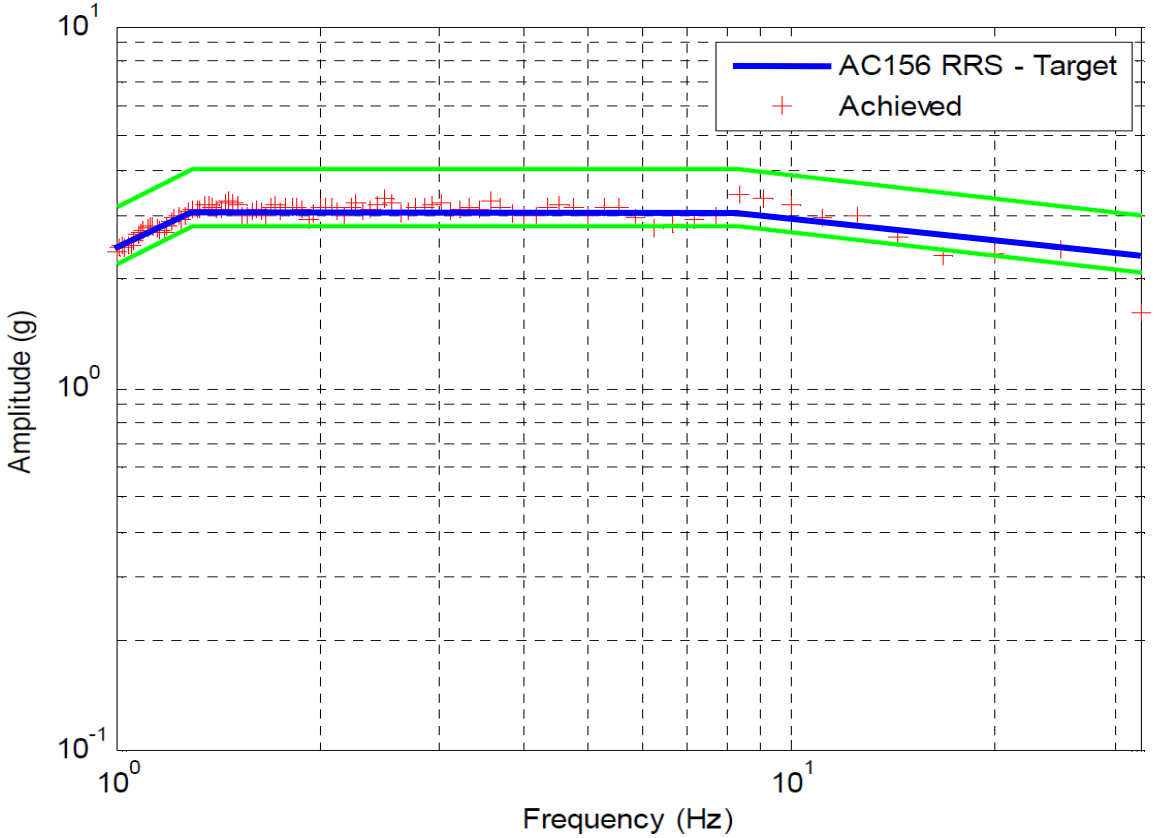
Typical Shake Table Input Time History

- Testing Time History
  - The duration of the record was set to 30 sec

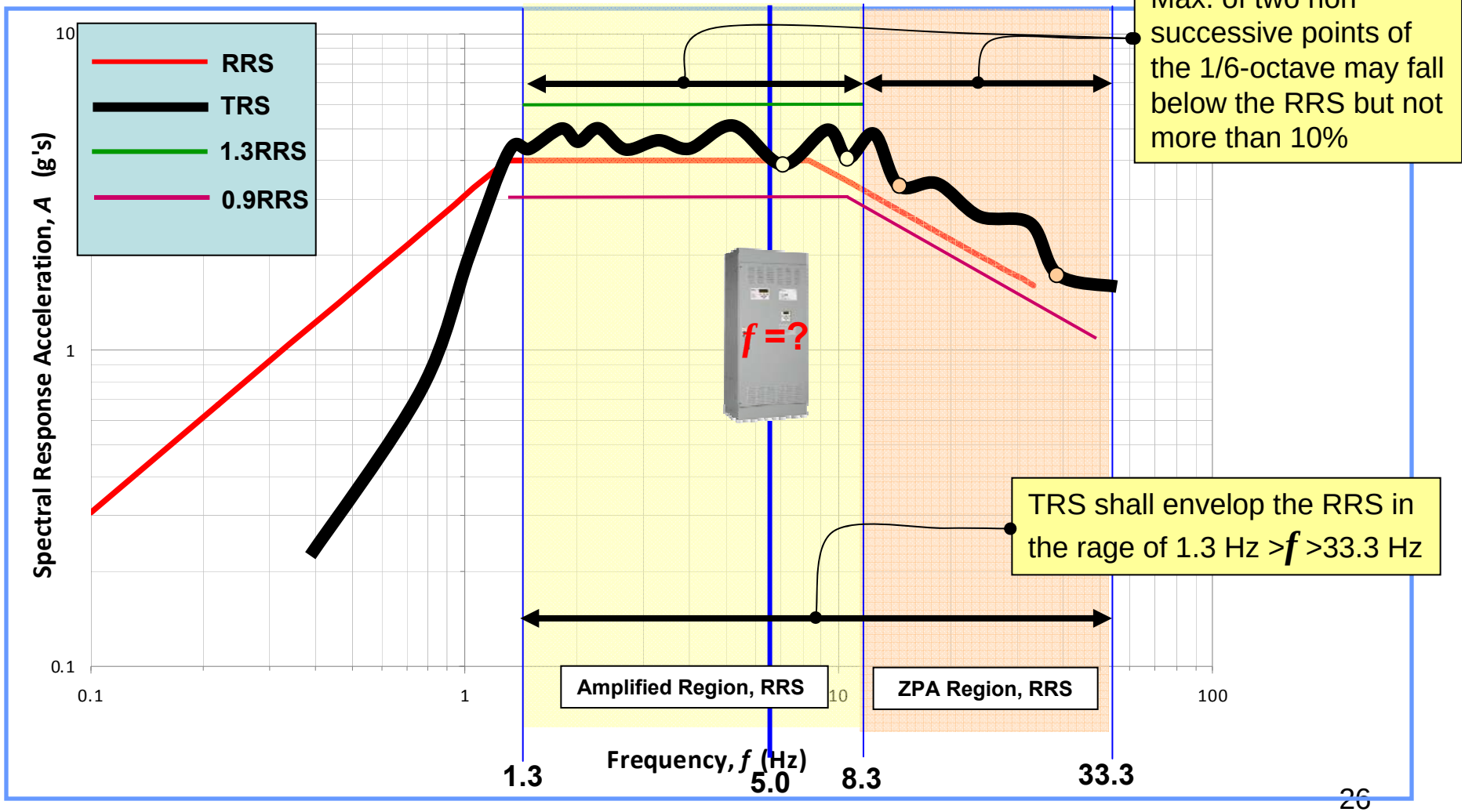


Typical Shake Table Achieved Test Response Spectra (TRS)

- Comparison of Achieved (TRS) 5% Damped Spectra and AC156 RRS

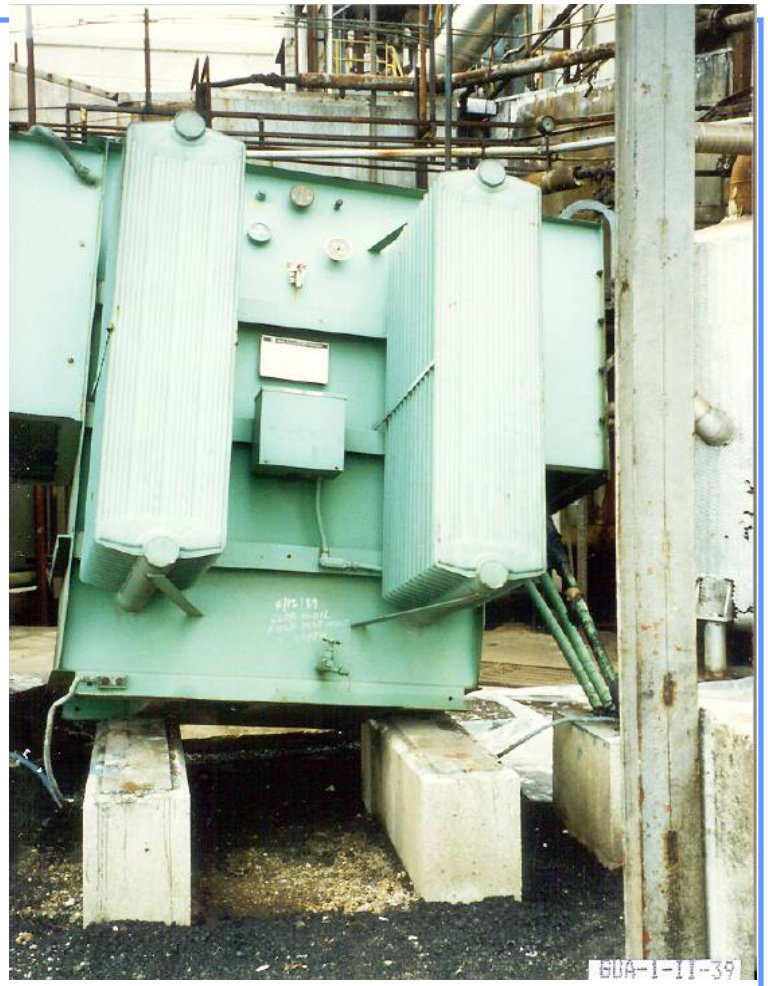


ICC-ES AC 156 Acceptance Criteria (Based on 1/6th Octave Band Analysis)



Seismic Qualification by Experience

- Requirements for Qualification by Experience Data
  - Characterization of experience motions as measured by instruments
  - Verification of post-earthquake performance
  - Equipment must be of equal or better construction
  - Project seismic demand must be less than qualification basis
  - Requires maintenance of data base for continuous evaluation of the performance of installed equipment experiencing new earthquake



OSHPD CAN 2-1708A.5

State of California **Office of Statewide Health Planning and Development**

CODE APPLICATION NOTICE

Subject: Certification of Equipment and Nonstructural Components

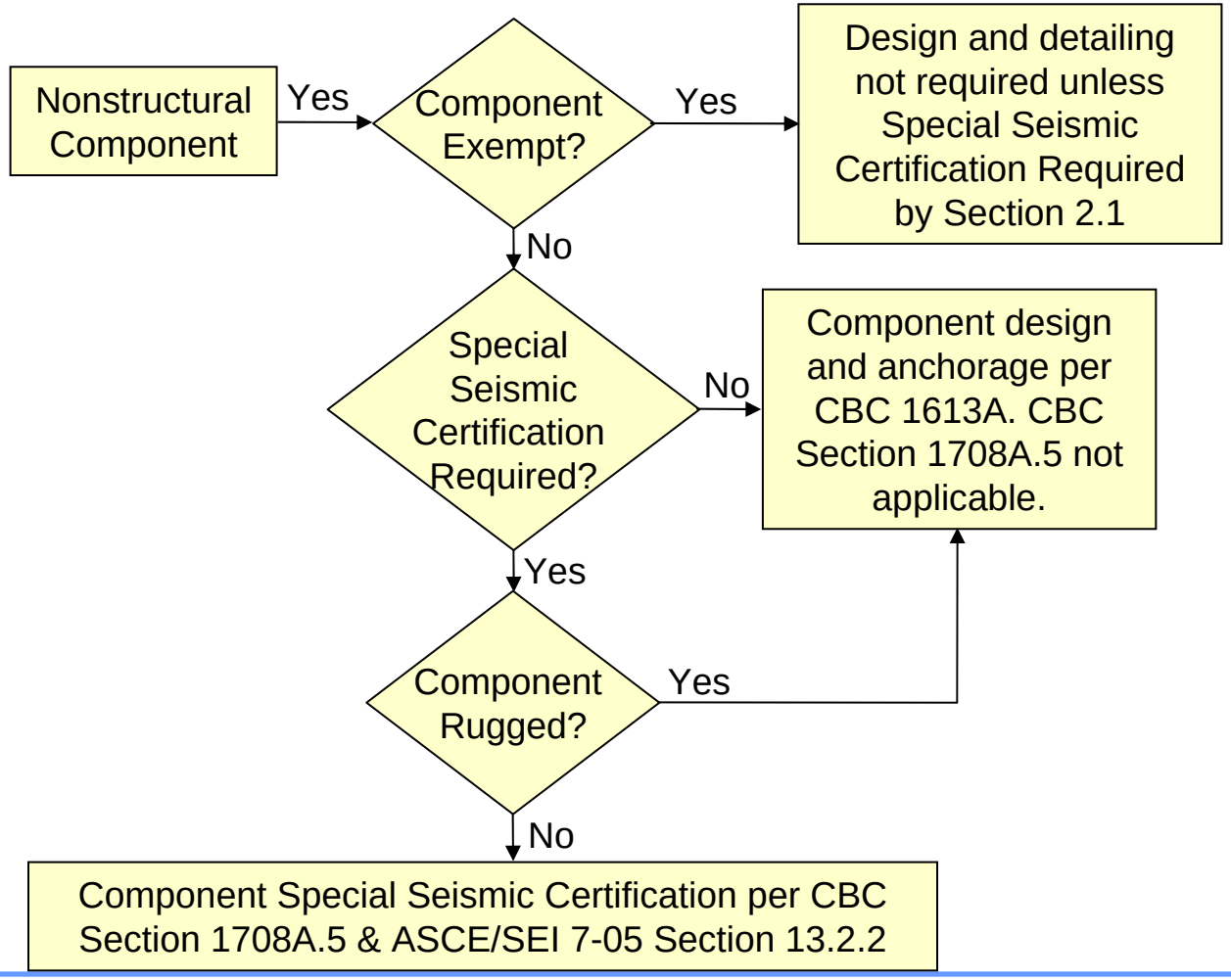
CAN NO. 2-1708A.5
EFFECTIVE: 10/31/08
REVISED: 6/26/09

CODE SECTIONS

Sections 1708A.2, 1708A.5, 1702A and 1707A.9
2007 California Building Code (CBC)
(see Appendix A)

Sections 13.2.1, 13.2.2, 13.2.5, 13.2.6, 13.1.3 and 13.1.4
American Society of Civil Engineers (ASCE/SEI)
7-05 Minimum Design Loads for Buildings and Other Structures
(see Appendix A)

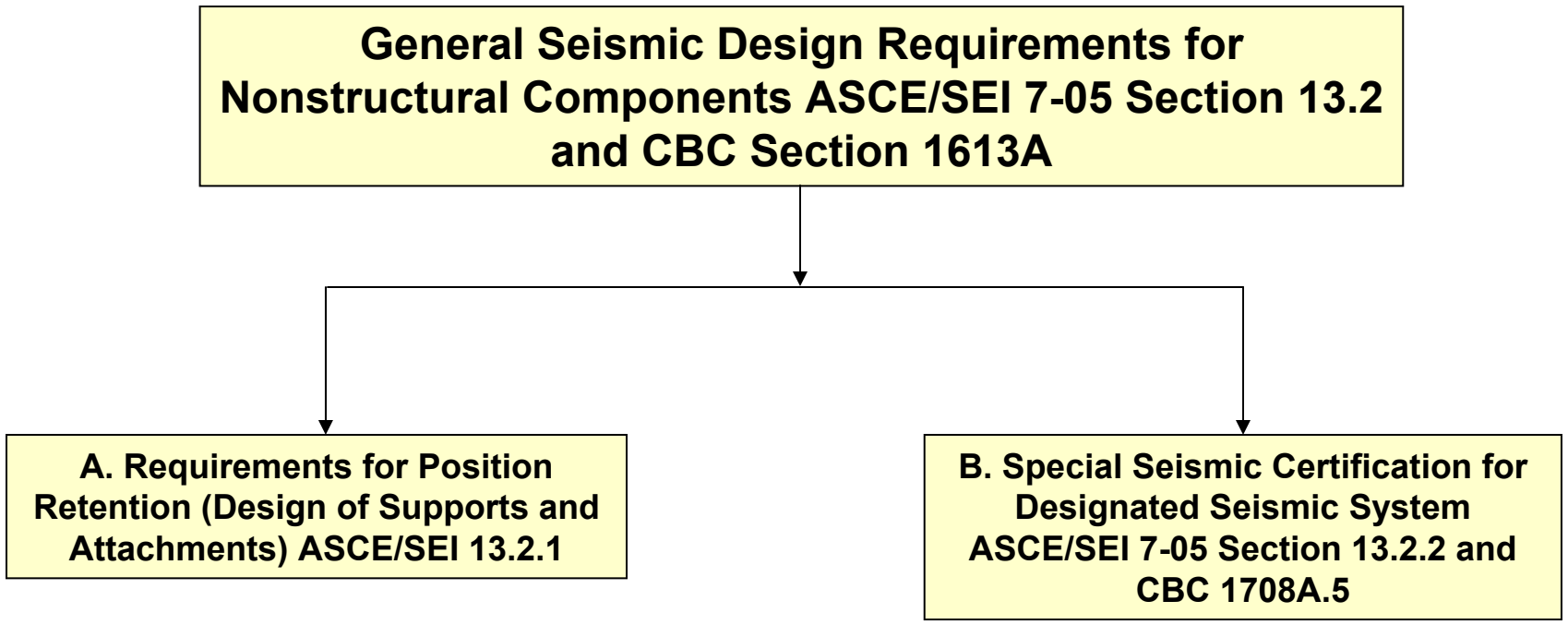
CAN 2-1708A.5: Identification of Seismic Design Parameters



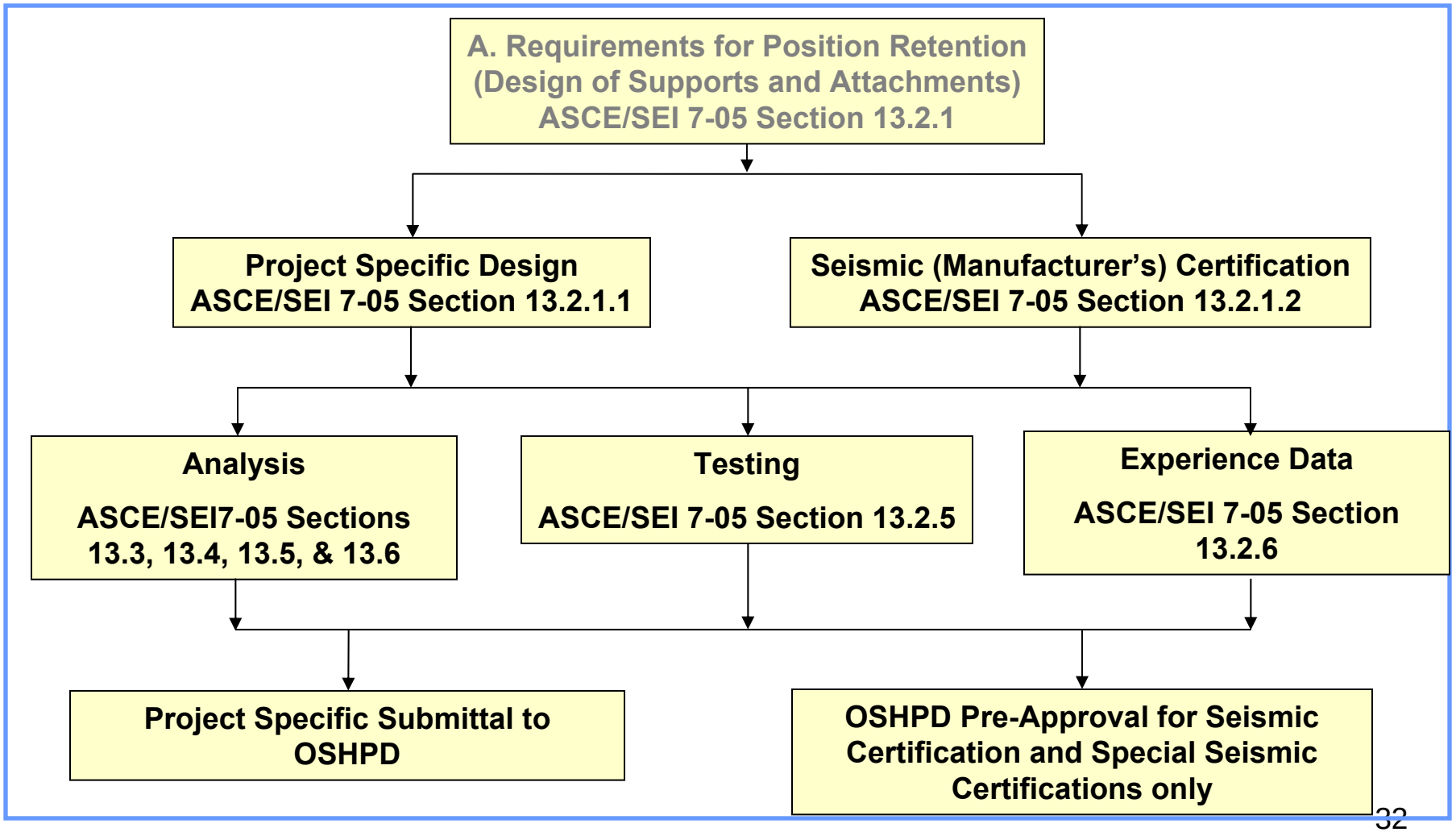
CAN 2-1708A.5 Section 2.1: List of Equipment and Components Requiring Special Seismic Certification

1. Emergency and standby power systems equipment including generators, turbines, fuel tanks, and automatic transfer switches.
2. Elevator equipment (except elevator cabs).
3. Smoke control fans.
4. Switchgear.
5. Motor control centers.
6. X-Ray machine(s) in the fluoroscopy room
7. Transformers.
8. Electrical substations.
9. UPS and associated batteries.
10. Distribution panels including electrical panel boards.
11. Control panels, including fire alarm, fire suppression, preaction, and auxiliary or remote power supplies.

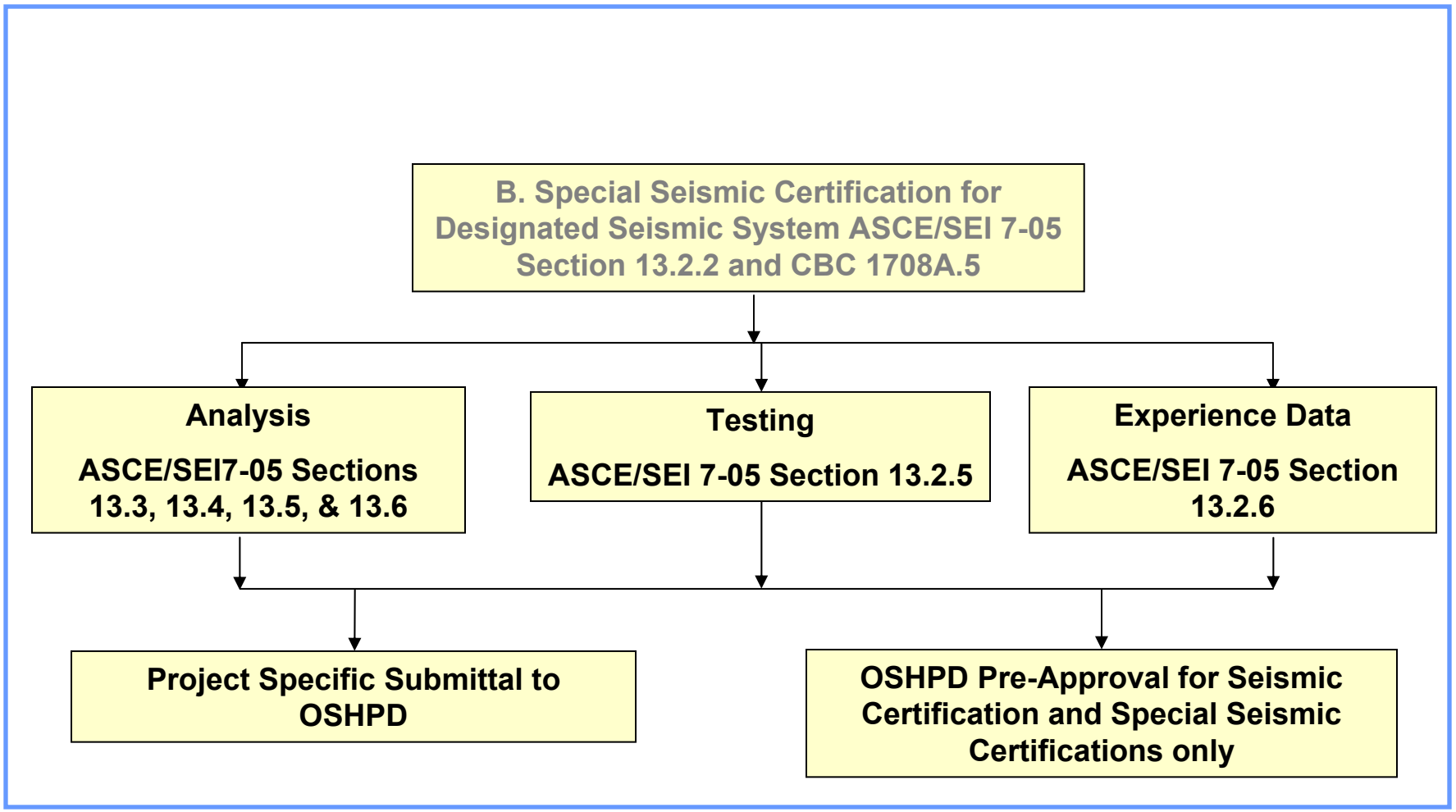
CAN 2-1708A.5: Position Retention vs. Special Seismic Certification



CAN 2-1708A.5: Position Retention and Seismic/Manufacturer's Certification



CAN 2-1708A.5: Special Seismic Certification / Seismic Qualification



CAN 2-1708A.5 Section 4.1: Approval by Analysis

- All analysis submitted to OSHPD shall be prepared pursuant to Section 7-115 of the 2007 CAC.
- Active parts or energized components:
  - Certified exclusively on the basis of shake table testing ; or,
  - Experience data,
  - Unless component is inherently rugged
    - By comparison with similar seismically qualified components.
- Multi-component system:
  - Where active parts or energized components are certified by tests or considered to be rugged, connecting elements, attachments, & supports can be justified by supporting analysis.

CAN 2-1708A.5 Section 4.2 Approval by Testing

All tests shall be performed by:

- An independent laboratory having accreditation to the ISO Accreditation Standard 17025 by an organization such as the IAS of ICC; or,
- Under the responsible charge of a California Licensed structural (S.E.), civil (C.E.) or mechanical engineer (M.E.).

- Test reports shall be prepared by:
  - A California Licensed S.E., C.E., or M.E.
  - Test reports prepared by a California Licensed C.E. or M.E., they shall be reviewed and accepted by a California licensed S.E.

CAN 2-1708A.5 Section 4.2
Approval by Testing (Continued)

- Where Individual components of a multi-component system certified by test:
  - The flexibility of the supporting structure in the equipment to point of anchorage shall be replicated in the test setup.
  - Alternately, the input motions for the test setup may be modified to account for this flexibility.

- Special seismic certification of a multi-component system:
  - Where individual components are certified by tests or considered rugged, connecting elements, attachments, and supports can be justified by supporting analysis.

How Many Test are Required?

4.2.1.1 Dynamic Test

- **A minimum of two tests are required:**
  - -Unless specified otherwise in the test standard;
    or,
  - - One dynamic test may be acceptable:
    - - Provided that, a single product (and not a product line with more than one product with variations) is certified in accordance with the OSHPD CAN **and** manufacturing process is ISO 9001 certified.

- **Where a range of products is tested:**
  - -The two tests should be on the smallest and largest units.

OSHPD Special Seismic Certification Preapproval (OSP) at OSHPD Website

OSHPD Special Seismic Certification Preapproval (OSP) form is available at:

http://www.oshpd.ca.gov/FDD/Pre-Approval/index.html

List of Equipment and Components with Special Seismic Certification is available at:

http://www.oshpd.ca.gov/FDD/Pre-Approval/special_seismic_cert_pre-approval.html

OSHPD Pre-Approval Web Page

Office of
Statewide Health Planning and Development oshpd

Home » FDD » **Pre-Approval**

Facilities Development Division (FDD) Anchorage and Special Seismic Certification Pre-Approvals

FIXED HOSPITAL EQUIPMENT ANCHORAGE AND SPECIAL SEISMIC CERTIFICATION (SEISMIC QUALIFICATION OR SPECIAL CERTIFICATION) PRE-APPROVALS

The OSHPD Anchorage Preapproval (OPA) and OSHPD Special Seismic Certification Preapproval (OSP) Programs operate under the SB 1953 Seismic Retrofit Program within FDD. These Programs review and pre-approve, as warranted, anchorage and special seismic certification of equipment and components to be used in health facility construction.

OSHPD FDD is currently accepting application for OPA and OSP based on the California Building Code, 2007 (CBC 2007). Beginning on March 1, 2010, OSHPD FDD will only accept OPA and OSP applications based on the CBC 2010 in preparation for enforcement of the CBC 2010 starting on January 1, 2011.

Application forms and currently approved OPA and OSP lists are provided below:

Listing of Pre-Approved Fixed Hospital Equipment Anchorages
For 2007 OSHPD Pre-Approvals

Listing of Pre-Approved Fixed Hospital Equipment Anchorages
For 2001 OSHPD Pre-Approvals

Listing of Pre-Approved Fixed Hospital Equipment Anchorages
For 1998 R's

Application for Pre-Approval of Anchorages for Fixed Hospital Equipment

Application for Pre-Approval - Special Seismic Certification of Equipment and Components - Microsoft Word

List of Equipment / Components with OSHPD Special Seismic Certification Preapproval (OSP)

OSP Listing at OSHPD Web Page

Office of
Statewide Health Planning and Development oshpd

Home » FDD » Pre-Approval » special seismic cert pre-approval

Facilities Development Division (FDD) List of Equipment / Components with OSHPD Special Seismic Certification Preapproval (OSP)

Seismic Qualification of Mechanical and Electrical Equipment Equipment and Components with OSHPD Special Seismic Certification Preapproval (OSP)*							
OSHPD Special Seismic Certification Number	Manufacturer	Product Type	Model	Spectral Response Acceleration at Short Period S_{DS} (g)	Height Factor Ratio (z/h)	Expiration Date	Comments
OSP-0001-10	Baltimore Air Coil	Cooling Tower	PT2 Basic	0.62	1	December 31, 2012	Tower 7.4 x 9 without X-Brace
			PT2 Upgraded	1.83	1	December 31, 2012	Tower 7.4 x 9 with X -Brace
OSP-0002-10	Baltimore Air Coil	Cooling Tower	Series 3000	0.9	1	December 31, 2012	Single Stack Open Tower
			Series 3000	0.9	1	December 31, 2012	Double Stack Open Tower
OSP-0003-10	Nortel Networks	PBX and Battery	Option 11C, Option 61 -81, & NTAK75 Battery Box (Option 11C)	1.9	1	December 31, 2012	Call Processing and Telephony Services System to Enterprises
OSP-0004-10	SimplexGrinnell	Fire Alarm Control Panel	4100U	2	1	December 31, 2012	
OSP-0005-10	Russelelectric	Transfer / Bypass Isolation Switches and Low-Voltage Switchgear	See attachments	2	1	December 31, 2012	Conditions in the test reports shall apply

California's Seismic Risk*

- California has a 99% chance of experiencing an earthquake of magnitude 6.7 or greater in the next 30 years
  - The chance is 97% in Southern California
  - The chance is 93% in Northern California
- California has a 23% chance of a magnitude 6.7+ EQ between 2013 and 2020
- Chance of even larger EQs in California in the next 30 years:

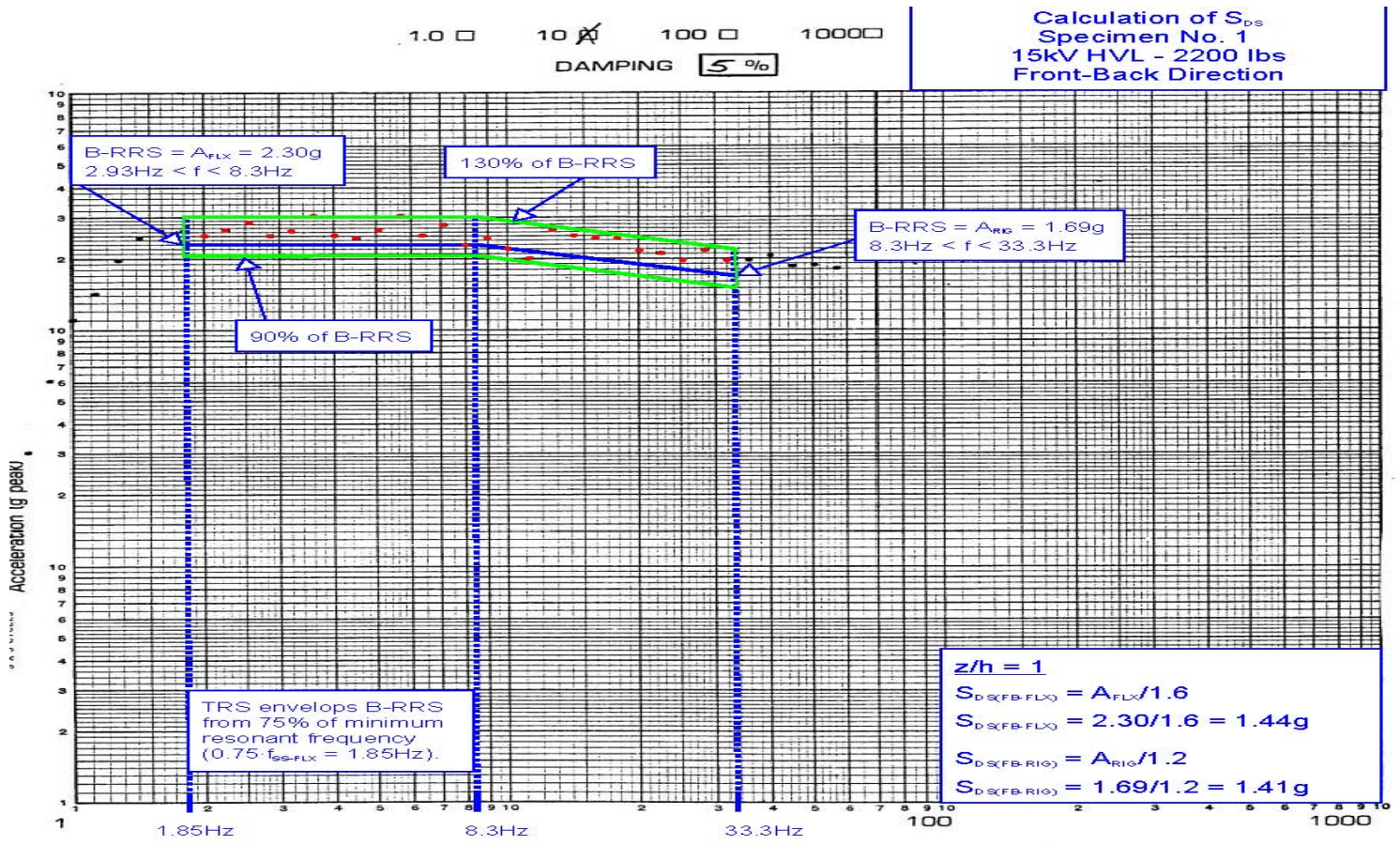
  > 7.0: 94%
  > 7.5: 46%
  > 8.0: 5%

*Data from USGS estimates

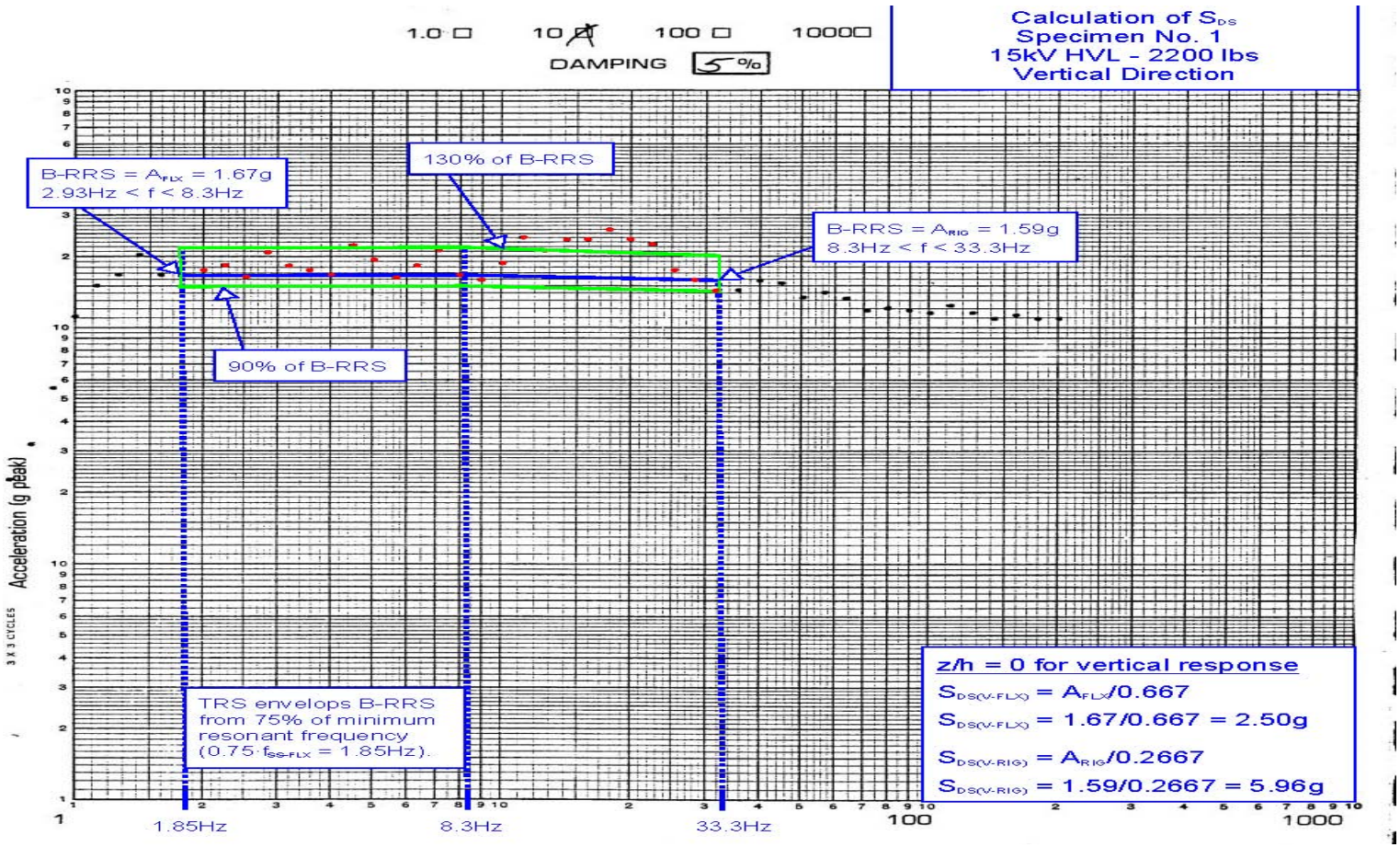
Any Questions or Comments?

- Any Questions?
- Any Comments?
- Any Suggestions?

Using Existing Test Data to Qualify Under the CBC 2007



Using Existing Test Data to Qualify Under the CBC 2007



Using Existing Test Data to Qualify Under the CBC 2007

#1 – 15kV (2,200 lbs)	S_{DS} (back-calc'ed from A_{FLX})	S_{DS} (back-calc'ed from A_{RIG})
Front-Back	1.44	**1.41**
Side-Side	1.64	1.56
Vertical	2.50	5.96

IEEE 344: Seismic Qualification of Equipment for Nuclear Power Generating Stations

- Performance requirements during and/or following one Safe Shutdown Earthquake (SSE) event preceded by a number of Operating Basis Earthquake (OBE) events
- Linear-elastic performance
- Operational through event
- Not Building Code based

Telcordia GR-63-Core: Seismic Qualification Test Protocol

- Telcordia GR-63-Core -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

Summary of Design and Required Response Spectra and Requirements of Test Time History from Various Testing Protocols/Building Codes

		IEEE 693 1997	AC156	IEC-1999	GR-63	RG-1.60	UBC-1997	IBC 2006
Design Spectrum or RRS	Damping, %	2	5	2,5,10	2	0.5,2,5,7,10	5	5
	Site-Dependency	NO	YES	NO	NO	NO	YES	YES
	Amplification factor	2	1.6	2[7]	Included	NA	NA	NA
	Frequency range, Hz	0.333	0.1–33.3	0.1–35	0.3–50	0.25–33		
	Plateau range, Hz	1.1–8.0	1.3–8.3	1.6–11.7[3)]	2.0–5.0[4]	2.5–9.0	Varies	Varies
	Spectral acceleration at plateau, in fractions of PGA	3.24	2.5 (at 5%)	5.0 (at 2%)	3.13 (Zone 4)	2.9[1] (at 5%)	2.5	2.5
Input Time History	Duration, sec	20	26–34	5–10	32	NA	NA	NA
	High-peaks count (≥ 70%)	NA	NA	3–20	NA	NA	NA	NA
	Strong part to duration ratio, %	NA	NA	25,50,75	NA	NA	NA	NA
TRS	Tolerance above RRS, %	NA	30	50[2]	30	NA	NA	NA
	Tolerance below RRS, %	NA	10[5]	0[2]	0	10[6]	NA	NA
	Tolerance range, Hz	NA	1.3–8.3	Not specified	1.0–7.0	NA	NA	NA
	Tolerance resolution, octave bands	NA	1/6	1/12(2%),1/6(5%)	1/6(2%)	~1/8	NA	NA
	Meets or exceeds range, Hz	1/T–33	0.7/T(or 3.5)–33	Not specified	1.0–50.0	Not specified	NA	NA
	Meets or exceeds resolution, octave	NA	1/3	Not specified	1/6(2%)	NA	NA	NA

Notes:
[1] The plateau has some slope and varies from 3.13–2.61; average value is presented.
[2] Individual points outside of tolerance zone can be acceptable provided such points do not coincide with the resonant frequency.
[3] Plateau start frequency is taken as 2.0 Hz if resonant frequency is more than 1 Hz.
[4] For Zone 4 (in case of Zone 3 the range is from 1.0 to 5.0 Hz and for Zones 1 and 2 the range is from 0.6–5.0 Hz).
[5] Individual points up to 10% below the RRS can be acceptable provided the adjacent 1/6 octave points are at least equal to the RRS.
[6] No more than 5 points of the spectra obtained from the time history should fall, and no more than 10% below the design spectra.
[7] For very flexible supporting structure the amplification factor is taken as 3.

OSHPD Special Seismic Certification Preapproval (OSP)

- For OSP of a product line with **similar structural configuration**, OSHPD requires:
  - Testing of at least two units (typically the smallest & largest units) and verification of similarities for interpolated units (see CAN 2-1708A.5 Section 4.2.1.1).

OSP Requirements (Continued)

- If the units are to be qualified for conditions with and without vibration isolators/different mounting types (e.g. wall mounted vs. floor mounted, etc.), they shall be tested for those configurations (see CAN 2-1708A.5 Section 4.2).

OSP Requirements (Continued)

- Multiple units can be tested on a single shake table simultaneously (provided table is capable of achieving the RRS with total payload).

Test Facility Requirements

- All tests shall be performed by an independent laboratory having accreditation to the International Standards Organization (ISO) accreditation standard 17025, or.
- Shall be under the responsible charge of a California Licensed structural, civil or mechanical engineer.

Test Report Requirements

- Test reports shall be prepared by a California Licensed structural, civil or mechanical engineer.
- If test reports are prepared by a California Licensed civil or mechanical engineer, they shall be reviewed and accepted by a California licensed structural engineer.

OSP Requirements (Continued)

- OSHPD strongly recommend that the Owner and his California licensed structural engineer agree on a test plan with OSHPD prior to any testing to ensure that there will be no issues with the OSP approval down the road.

OSP Submittal Requirements

- Completed application in word format with signature attached in Section 3.0 of the application form.
- Application review fee of $5,000.00 payable to “OSHPD”.
- Complete test reports in electronic form that satisfy minimum content requirements by OSHPD.
- Verification of similarities for interpolated units in the form of manufacturer's catalog and/or schematic cut sheets.

Statutory OSHPD Review Requirements

§129680. Hospitals housing patients less able to protect themselves; Legislative Intent

(a) It is the intent of the Legislature that hospital buildings that house patients who have less than the capacity of normally healthy persons to protect themselves, and that must be reasonably capable of providing services to the public after a disaster, shall be designed and constructed to resist, insofar as practical, the forces generated by earthquakes, gravity, and winds. In order to accomplish this purpose, **the office shall** propose proper building standards for earthquake resistance based upon current knowledge, and **provide an independent review of the design** and construction of hospital buildings.

The California Building Code, 2007

1601A.3 Enforcement Agency Approval. *In addition to requirements of California Code of Regulations (C.C.R.) Title 24, Parts 1 & 2,* ***any aspect of project design****, construction, quality assurance, or quality control programs* ***for which this code requires approval by the design professional, are also subject to approval by the enforcement agency.***

Are Third Party Review Subject to OSHPD Review?

- **<u>Yes</u>**
- Required by Statute
- Required by the CBC 2007 Section 1601A.3

Can the Analysis be Bookended Similar to Testing?

- **No**

- Analysis is only good for the unit analyzed (limited variations and/or grouping may be acceptable)

- Since analysis of the smallest and largest buildings (under OSHPD jurisdiction) can't be used for permitting all OSHPD buildings (of a given structural configuration).

- However, testing of a few connections to verify a analysis methodology can justify all connections of similar configurations

What R_p can be used for Special Seismic Certification?

- R_p = 1.0 for Special Seismic Certification
- ASCE 7-05 do not provide R_p values for special seismic certification
- Support of critical equipment and components should remain essentially elastic for post-earthquake functionality

Can the Active Mechanical and Electrical Equipment get an OSP by analysis alone?

- **No**

- Active and energized components must be certified by shake table testing or experience data.

- ONLY connecting elements, attachments, and supports can be justified by supporting analysis for active and energized components

Is the Component Design at Global Level only Enough?

- **No**

- All components shall be designed in accordance with the code (both demand and capacity shall be based on code).

- Stability and local affects shall be part of the design as required by the code.

- The CBC 2007 does not permit 1/3rd allowable stress increase for most materials, including steel and concrete.

What will it take to make R_p greater than 1.0 for Special Seismic Certification?

- Need to account for system overstrength and inelastic deformation including strength and stiffness degradation of each structural element and nonstructural component (may require non-linear dynamic analysis)
- Need to model flexibility/stiffness of each structural element and nonstructural component
- Need to define limit state for each structural element and nonstructural component in terms of stress and deformation
- Need to verify model with benchmark fragility test and identify the source of non-linearity that will account for higher Rp value.
- Materials need to be traced in accordance with the CBC 2007
- Fabrication/Installation inspection and testing shall be in accordance with the CBC 2007
- Since a number of items above are not defined in the code, a project specific structural design criteria approval will be required