Guideline Documents

30 PROTA Symposium:

New Generation of Seismic Codes and New Technologies in Earthquake Engineering

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Why PBD for Tall Buildings?

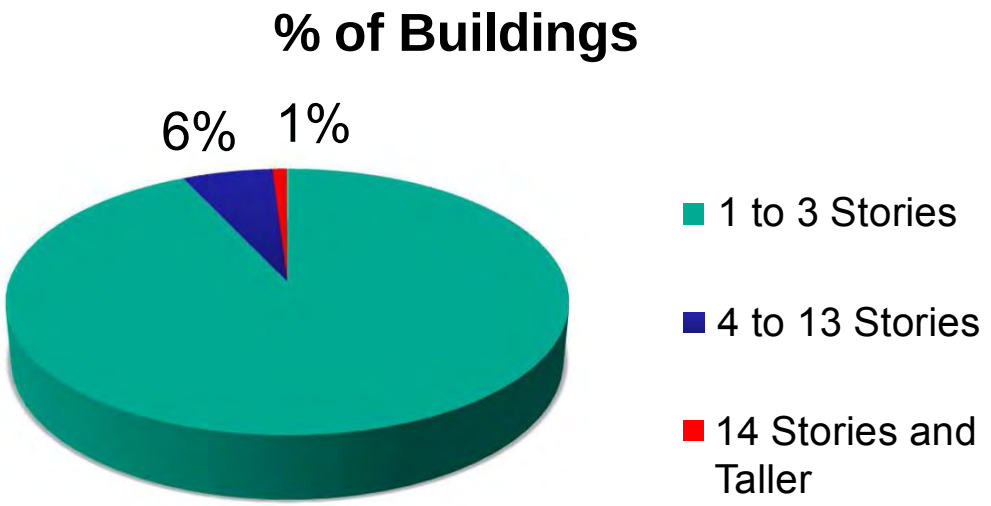
- The traditional code-based design everywhere is built on prescriptive rules and linear analysis.
- Using such an approach:
  - We can design building that are generally life-safe during earthquakes
  - They generally have more capacity than indicated by our design analysis
- But how much more capacity they have got?
- What level of excitation is necessary to bring them down?
- The prescriptive code approach is incapable of answering these questions.

Why PBD for Tall Buildings?

- Tall Buildings are a special class of structures with very particular characteristics and requirements:
  - long period
  - multi-mode behavior
  - Significance of P-delta effects
  - large occupancy
  - impact of failure and/or collapse
- We have evolved: from linear static to dynamic to nonlinear; from deterministic to probabilistic.
- Computing advances have made nonlinear analysis practical.

Why PBD for Tall Buildings?

- In fairness to the code-writers, codes are not generally written with tall buildings in mind.
- Let us look at building construction statistics in the United States:



- You can not realistically expect code-writers to dedicate a large portion of their effort to address 1% of the buildings.

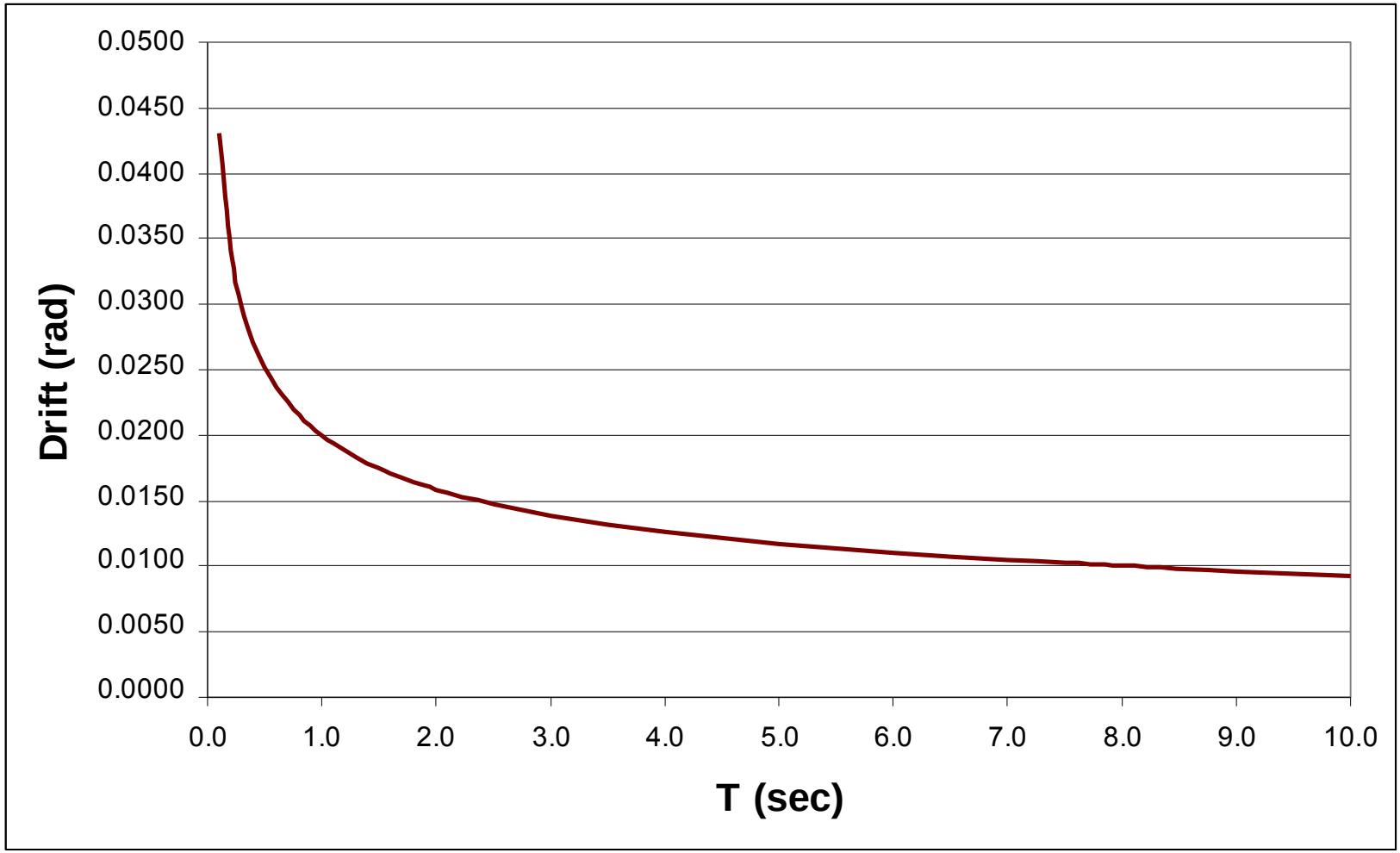
Example:

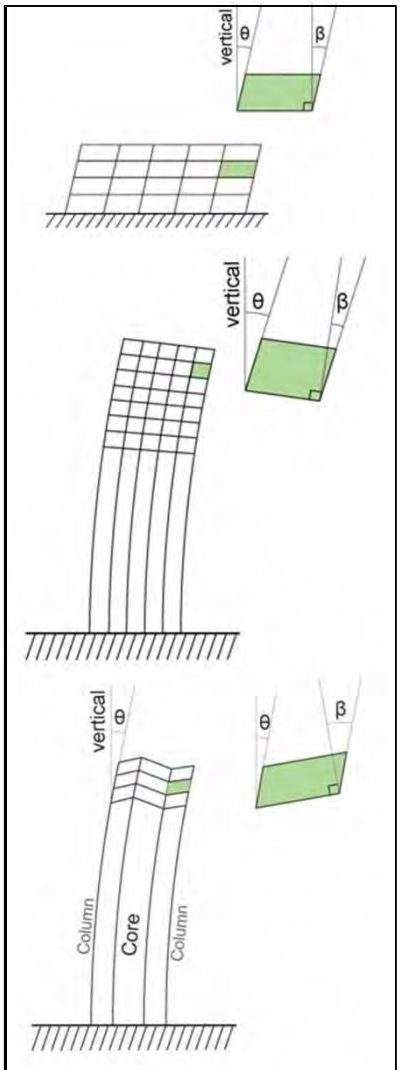
- 2002 Los Angeles Building Code Story Drift Requirement:

$$\textit{Story Drift Ratio} \leq \mathbf{0.020/T^{1/3}}$$

- This provision, which was later retracted, probably did not have a serious effect on design of low-rise buildings but was a huge straightjacket for design of tall buildings with long vibration periods

Example:





Illustrations courtesy of *CTBUH*

Examples of the Need

- Core Wall System
  - The great majority of tall buildings under design or construction in western U.S. use this system.
  - But codes do not allow shear wall alone systems to exceed 240 feet of overall height.
  - How did they get around that limitation?
- How about hybrid systems or new systems not envisioned by the code?

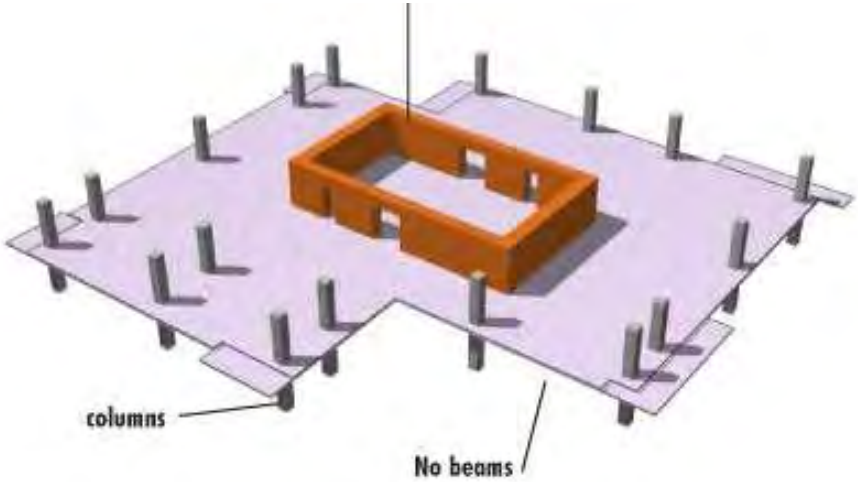


Figure courtesy of MKA

The Mechanism

- Alternative Methods Clause in the Codes
  - Section 104.11 of 2012 IBC:
    - "The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety."

The Mechanism

- Alternative Methods Clause in the Codes
  - Section 12.6 of ASCE 7-10:
    - *"The structural analysis required by Chapter 12 shall consist of one of the types permitted in Table 12.6.1, based on the structure's seismic design category, structural system, dynamic properties, and regularity, or with the approval of the authority having jurisdiction, an alternative generally accepted procedure is permitted to be used....."*
    - Section 1.3 of ASCE 7-10 also permits performance-based approaches that use analysis, testing, or a combination thereof, as acceptable alternative means.

There is a problem though!

- How do you establish equivalent or superior performance?
- You need:
  - An acceptable methodology
  - Acceptable seismic hazard evaluation methods
  - Acceptable modeling and analysis techniques
  - Rational acceptance criteria

That is where guidelines come in!

Guidelines

- The two mostly used guidelines are:
  - 2010 PEER-TBI
  - 2014 LATBSDC
- They both refer to:
  - ASCE 41and ASCE 7 Standards
  - ATC-72-1
- Jurisdictional differences in adaptation:
  - Los Angeles
  - San Diego
  - San Francisco
  - Seattle

2010 PEER-TBI Organization

104 pages

1. Introduction
2. Design Performance Objectives
3. Design Process Overview
4. Design Criteria Documentation
5. Seismic Input
6. Preliminary Design
7. Service Level Evaluation
8. MCE Evaluation
9. Presentation of Results
10. Project Review

2014 LATBSDC Organization

51 pages

1. Introduction
2. Intent, Scope, Justification, and Methodology
3. Analysis and Design Procedure
   1. General
   2. Modeling Requirements
   3. Serviceability Requirements
   4. Collapse Prevention Evaluation
   5. Specific Provisions for R/C Structures
4. Peer Review Requirements
5. Seismic Instrumentation

ASCE 41and the Guidelines

- ASCE41 is officially intended for seismic rehabilitation of existing structures
- However, its component-based performance limits for NDP are routinely referenced by guidelines for performance based design of tall buildings
- Engineers who believe ASCE 41limits are too conservative, or are not applicable to their project, have the opportunity to present and substantiate other appropriate limits
- Peer review approval is always necessary for any deviation from ASCE 41

Performance Objectives

- **2010 TBI:**
  - **Basic Performance Objective (BPO)**
    - **Performance equivalent to Code design buildings**
    - **Two Level Design**
  - **Enhanced Performance Objective (EPO)**
    - **Better than BPO**
    - **Specifics and criteria not laid out**
- **2014 LATBSDC:**
  - **Serviceable performance under frequent events**
  - **Repairable following very rare events**
- **Hazard Levels Considered:**
  - **Serviceability: 43 years mean return period (50% in 30 years)**
  - **Very Rare Event:**
    - **PEER-TBI: ASCE 7-05, 7-10 MCE**
    - **2014 LATBSDC: MCE_R per ASCE 7-10 with clarifications**

Analytical Procedures

- ASCE-41 permits four types of analyses:
  1. Linear elastic static procedure (LSP)
  2. Linear dynamic procedure (LDP) or response spectrum analysis
  3. Non-linear static procedure (NSP) commonly referred to as the push-over analysis, and
  4. Dynamic nonlinear response analysis (NDP).

- Tall Building Design Guidelines permit only two:
  1. 3D LDP or NDP for serviceability check
  2. 3D NDP for all checks

More About Performance Objectives

1. Serviceable behavior:
   - building structural and nonstructural components retain their general functionality during and after earthquake
   - Repairs, if necessary, are expected to be minor and could be performed without substantially affecting the normal use and functionality of the building
2. A low probability of collapse under MCE or MCE_R type events.
   - Demands are checked for all structural members (lateral as well as gravity system)
   - Claddings and their connections to the structure must accommodate MCE or MCE_R displacements without failure

Capacity Design

- Both guidelines use capacity design principles:
  - The capacity design criteria shall be described in the project-specific seismic design criteria.
  - The structural system for the building shall be clearly demonstrated to have well defined inelastic behavior where nonlinear action is limited to the clearly identified members and regions.
  - All other members should be stronger than the elements designed to experience nonlinear behavior.

Examp ch

the building that are designed to dissipate energy and exhibit significant ductility is the essence of Capacity Design.

Typical zones and actions commonly designated for nonlinear behavior are identified in the following table. This table is not meant to be conclusive. Other zones may be included into the design based on sufficient justification.

Table C.3.3.2 Zones and actions commonly designated for nonlinear behavior

Structural System	*Zones and Actions*
Special Moment Resisting Frames (steel , concrete, or composite)	· *Flexural yielding of Beam ends (except for transfer girders)* · *Shear in Beam-Column Panel Zones* · *P-M-M* yielding at the base of columns (top of foundation or basement podiums)*
Special Concentric Braced Frames	· *Braces (yielding in tension and buckling in compression)* · *P-M-M yielding at the base of columns (top of foundation or basement podiums)*
Eccentric Braced Frames	· *Shear Link portion of the beams (shear yielding preferred but combined shear and flexural yielding permitted).* · *P-M-M yielding at the base of columns (top of foundation or basement podiums)*
Unbonded Braced Frames	· *Unbonded brace cores (yielding in tension and compression)* · *P-M-M yielding at the base of columns (top of foundation or basement podiums)*
Special Steel-Plate Shear Walls	· *Shear yielding of web plates* · *Flexural yielding of Beam ends*
R/C Shear Walls	· *P-M-M yielding at the base of the walls (top of foundation or basement podiums) and other clearly defined locations throughout the height of the wall.* · *Flexural yielding and/or shear yielding of link beams*
Foundations	· *Controlled rocking* · *Controlled settlement*

* yielding caused by combined axial force and uniaxial or biaxial flexure

Source: 2014 LATBSD

Classification of Structural Actions

- All actions must be classified as either
  - Force-Controlled, or
  - Deformation-Controlled

- Force-Controlled actions must further be categorized as either
  - Critical, or
  - Non-Critical

Example of Classification of Actions

3.5.4.1 Acceptance Criteria at the Component Level

Actions in all lateral load resisting elements must be categorized as either force-controlled or deformation-controlled and if classified as force-controlled, as either critical or noncritical actions. Table 5 shows a representative and acceptable classification of such actions.

Table 5. Typical Classification of Component Actions

Component	Seismic Action	Classification	Criticality
Below grade perimeter walls	Flexure	Force Controlled	Non-Critical
	Shear	Force Controlled	Critical
Parking ramp walls	Flexure	Deformation Controlled	N/A
	Shear	Force Controlled	Critical
Podium walls	Flexure	Deformation Controlled	N/A
	Shear	Force Controlled	Critical
Tower core walls (over their entire height)	Flexure	Deformation Controlled	N/A
	Shear	Force Controlled	Critical
Core wall coupling beams	Shear / Flexure	Deformation Controlled	N/A
Floor slabs	Out of plane flexure around supports	Deformation Controlled	N/A
Diaphragms with major shear transfer	Flexure	Force Controlled	Non-Critical
	Shear	Force Controlled	Critical
Gravity columns	Axial	Force Controlled	Critical
Foundations	Flexure	Force Controlled	Non-Critical
	Shear	Force Controlled	Critical

Source: 2014 LATBSDC

Evaluation Procedures

- Both guidelines require a three-dimensional detailed mathematical model of the physical structure
- Realistic estimates of stiffness, strength and damping
- Strength:
  - 2014 LATBSDC uses expected material properties and reduction factor of 1.0.
  - 2010 PEER-TBI uses the same for MCE but specified properties and code reduction factors for serviceability evaluation.

Expected Material Strength

Table 2. Expected Material Strengths

Material		Expected Strength
		Strength (ksi)
Yield Strength for Structural steel		
	Hot-rolled structural shapes and bars	
	ASTM A36/A36M	$1.5F_y$
	ASTM A572/A572M Grade 42 (290)	$1.3F_y$
	ASTM A992/A992M	$1.1F_y$
	All other grades	$1.1F_y$
	Hollow Structural Sections	
	ASTM A500, A501, A618 and A847	$1.3F_y$
	Steel Pipe	
	ASTM A53/A53M	$1.4F_y$
	Plates	$1.1F_y$
	All other products	$1.1F_y$
Yield Strength for Reinforcing steel		1.17 times specified f_y
Ultimate Strength for Concrete		1.3 times specified f'_c

Table 3. Reinforced Concrete Stiffness Properties

Element	*Serviceability and Wind*	*MCE-Level Nonlinear Models*
Structural Walls	Flexural – 0.75 Ig Shear – 1.0 Ag	Flexural – 1.0 Ec *, ** Shear – 0.5 Ag

Stiffness Properties – 2010 PEER-TBI

Reinforcing Steel	All other Products	1.1 fy
Concrete		1.17 fy
		1.3 f'c

* fy is used to designate specified yield strength of steel materials in this Guideline. It is equivalent to Fy used in AISC standards.

Table 7.2 Effective component stiffness values.

Component	Flexural Rigidity	Shear Rigidity	Axial Rigidity
Structural steel Beams, Columns and Braces	E_sI	G_sA	E_sA
Composite Concrete Metal Deck Floors	$0.5E_cI_g$	G_cA_g	E_cA_g
R/C Beams – nonprestressed	$0.5E_cI_g$	G_cA_g	E_cA_g
R/C Beams – prestressed	E_cI_g	G_cA_g	E_cA_g
R/C Columns	$0.5E_cI_g$	G_cA_g	E_cA_g
R/C Walls	$0.75E_cI_g$	G_cA_g	E_cA_g
R/C Slabs and Flat Plates	$0.5E_cI_g$	G_cA_g	E_cA_g

Notes:

E_c shall be computed per ACI 318, using expected material strength per Table 7.1.

G_c shall be computed as $E_c / \left(2\left(1+n\right)\right)$, where n shall be taken as 0.2.

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Stiffness Properties – 2014 LATBSDC

Ultimate Strength for Concrete	1.3 times specified f'_c

Table 3. Reinforced Concrete Stiffness Properties

Element	*Serviceability and Wind*	*MCE-Level Nonlinear Models*
Structural Walls	Flexural – 0.75 Ig Shear – 1.0 Ag	Flexural – 1.0 Ec *, ** Shear – 0.5 Ag
Basement Walls	Flexural – 1.0 Ig Shear – 1.0 Ag	Flexural – 0.8 Ig Shear – 0.5 Ag
Coupling Beams	Flexural – 0.3 Ig Shear – 1.0 Ag	Flexural – 0.2 Ig Shear – 1.0 Ag
Diaphragms (in-plane only)	Flexural – 0.5 Ig Shear – 0.8 Ag	Flexural – 0.25 Ig Shear – 0.25 Ag
Moment Frame Beams	Flexural – 0.7 Ig Shear – 1.0 Ag	Flexural – 0.35 Ig Shear – 1.0 Ag
Moment Frame Columns	Flexural – 0.9 Ig Shear – 1.0 Ag	Flexural – 0.7 Ig Shear – 1.0 Ag

* Modulus of elasticity is based on the following equations:

$$E_c = 57000\sqrt{f_c} \quad \text{for } f'_c \le 6000 \text{ psi}$$

$$E_c = 40000\sqrt{f_c} + 1 \times 10^6 \quad \text{for } f'_c > 6000 \text{ psi} \quad \text{(per ACI 363R-92[1])}$$

** Nonlinear fiber elements automatically account for cracking of concrete because the concrete fibers have zero tension stiffness.

PEER-TBI & LATBSDC Provisions

1. Use 2.5% damping instead of 5% damping but permit DCR = 1.5 for deformation controlled members for serviceability.
2. 2014 LATBSDC limits DCR to 0.70 for force controlled members in serviceability check.
3. 2010 PEER requirements for collapse prevention are more elaborate and detailed than 2011 LATBSDC
4. No minimum base shear capacity requirement in either document

Analysis Methods

- Serviceability:
  - Can use either
    1. Linear Response Spectrum Analyses
       - CQC mode combination
       - 90% mass participation
    2. Nonlinear Dynamic Response Analyses

- For MCE evaluation:
  - Must use
    - Nonlinear Dynamic Response Analyses
- Inherent torsional properties of the structural system should always be considered.

Accidental Eccentricity (AE)

- 2014 LATBSDC
  - Consider implications during serviceability evaluation
  - Address if significant during MCE evaluation
- 2010 PEER TBI
  - Do not need to consider
- Consideration of AE in nonlinear analyses may require multiple evaluations.

Floor Diaphragms

- Floor diaphragms shall be included in the mathematical model using realistic stiffness properties.
- Regardless of the relative rigidity or flexibility of floor diaphragms, flexibility of diaphragms with significant force transfer (for example podium levels and other setback levels) shall be explicitly included in the mathematical model.
- Diaphragm chord and drag forces shall be established in a manner consistent with the floor characteristics, geometry, and well-established principles of structural mechanics.
- Both shear and bending stresses in diaphragms must be considered.
- At diaphragm discontinuities, such as openings and re-entrant corners, the dissipation or transfer of edge (chord) forces combined with other forces in the diaphragm shall be evaluated.

Load Combinations

accidental torsion are considered in order to establish whether accidental torsion needs to be included in the Collapse Prevention evaluation (see Section 3.5). The structure shall be evaluated for the following load combinations:

a) Response Spectrum Analysis

$$1.0D + L_{\text{exp}} + 1.0E_{\text{x}} + 0.3E_{\text{y}}$$

$$1.0D + L_{\text{exp}} + 1.0E_{\text{y}} + 0.3E_{\text{x}}$$

b) Nonlinear Dynamic Response Analysis

$$1.0D + L_{exp} + 1.0E$$

where D is the service dead load and L_{exp} is the expected service live load. L_{exp} may be taken as 25% of the unreduced live load unless otherwise substantiated and shall be included in all gravity calculations and P-D analyses.

C.3.4.3. Building Code response modification factors do not apply (that is, R, W_0, r, and C_d, are all taken as unity). L_{exp} need not be included in the mass calculations.

3.4.3.1. Elastic Response Spectrum Analyses

At least 90 percent of the participating mass of the structure shall be included in the calculation of response for each principal horizontal direction. Modal responses shall be combined using the

P-Δ Inclusion

- P-Δ effects must be included in all analyses

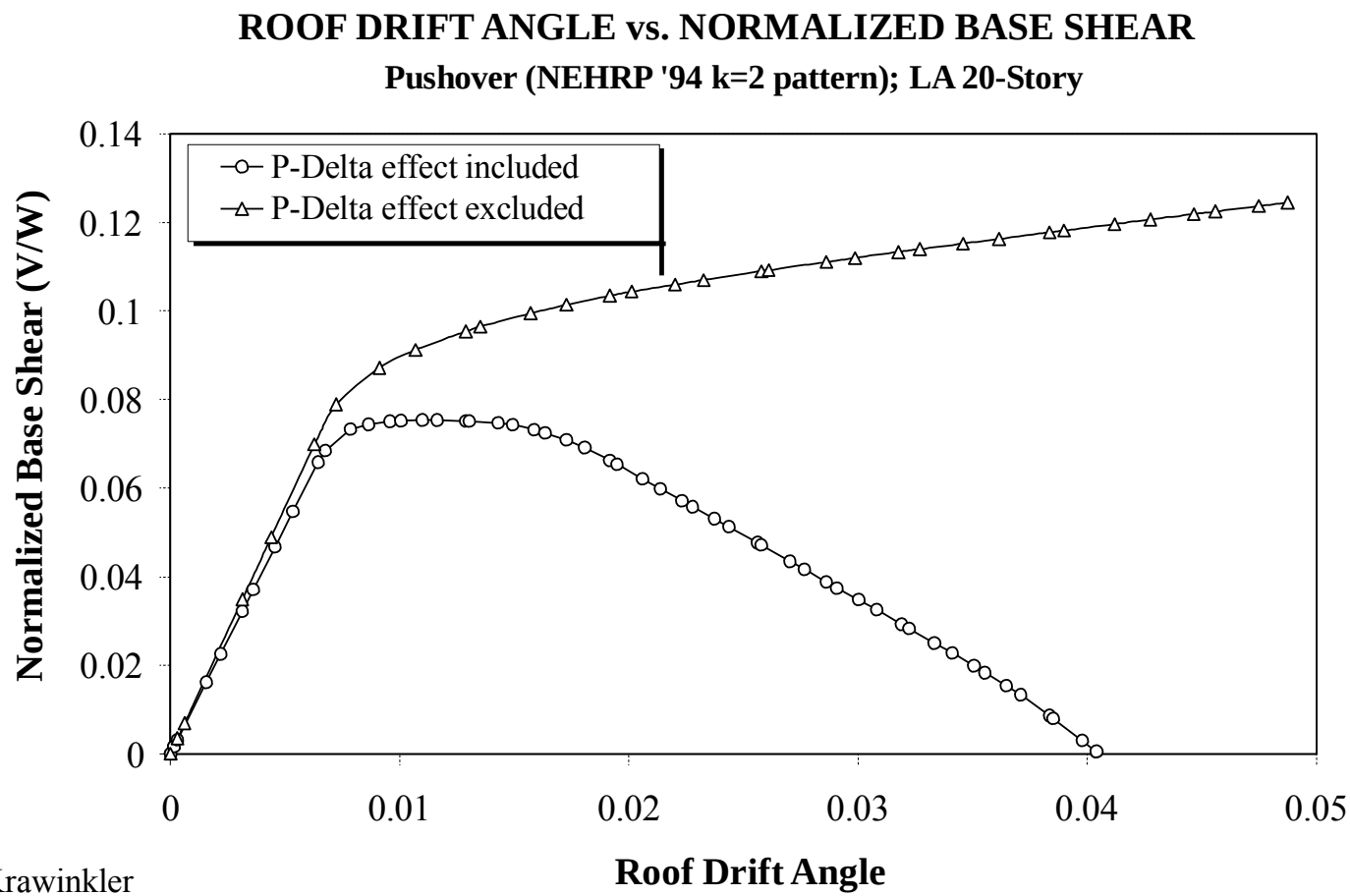


Figure courtesy of Prof. Helmut Krawinkler

Modeling Nonlinear Behavior

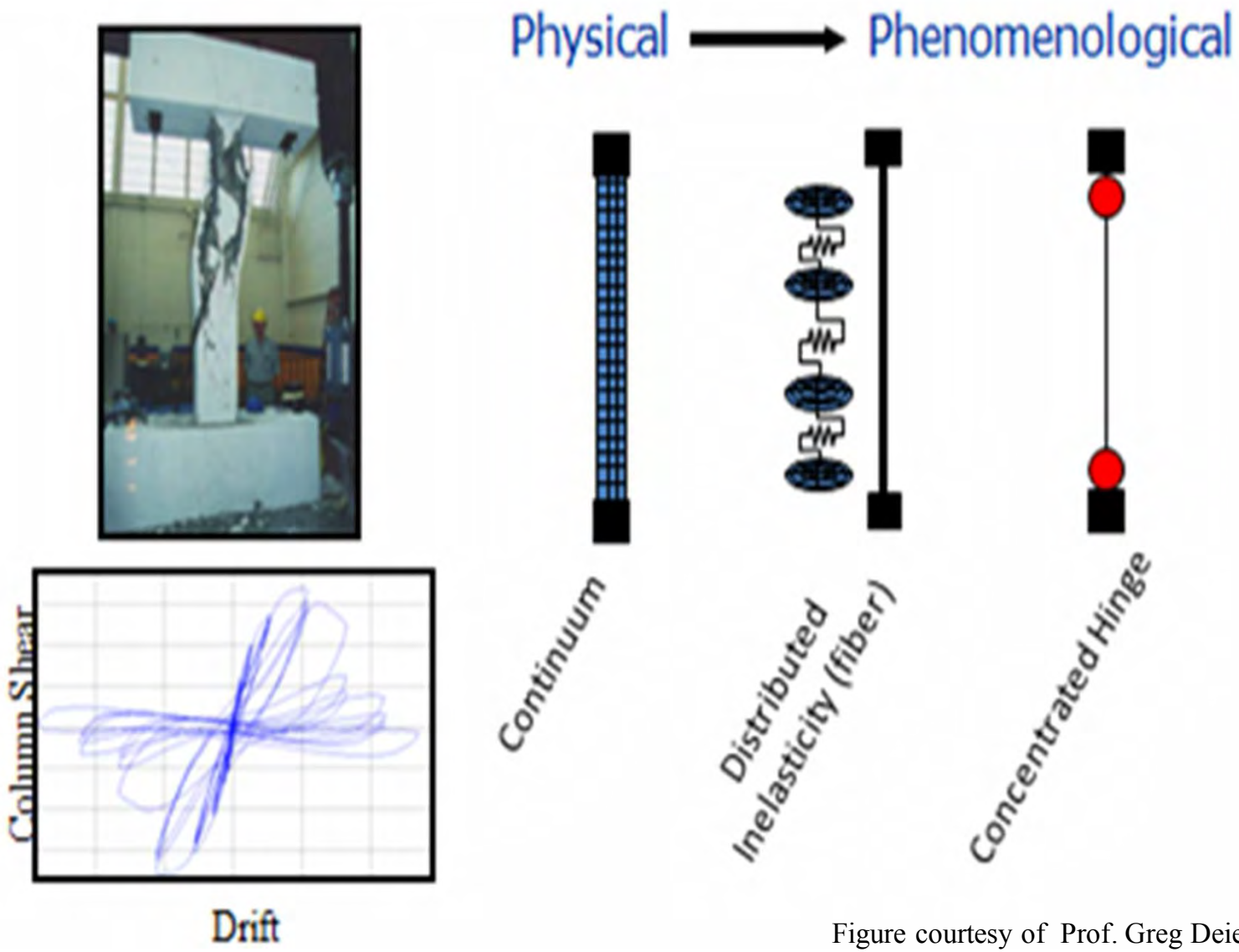


Figure courtesy of Prof. Greg Deierlein

Modeling Nonlinear Behavior

- Concentrated plasticity model for beams and columns and fiber elements for walls are most common
- All other elements and components that in combination significantly contribute to or affect the total or local stiffness of the building should be included in the mathematical model.
- Axial deformation of gravity columns in a core-wall system is one example of effects that should be considered in the structural model of the building

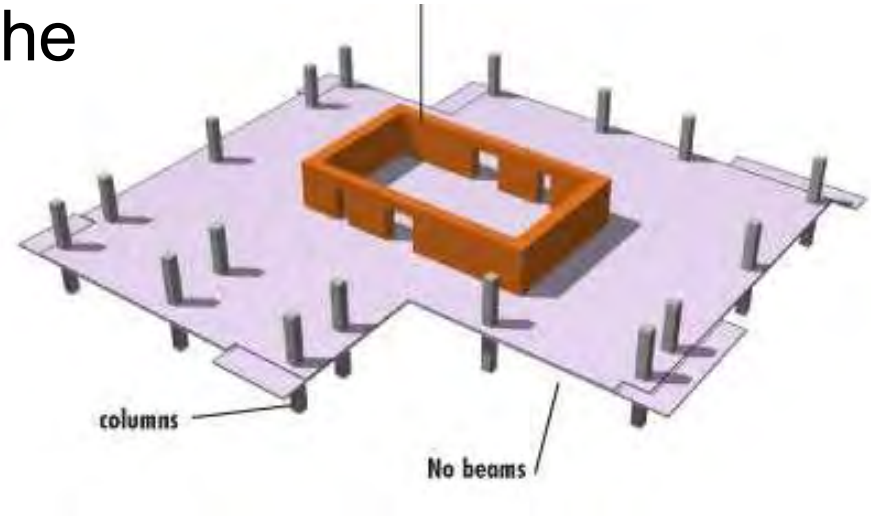
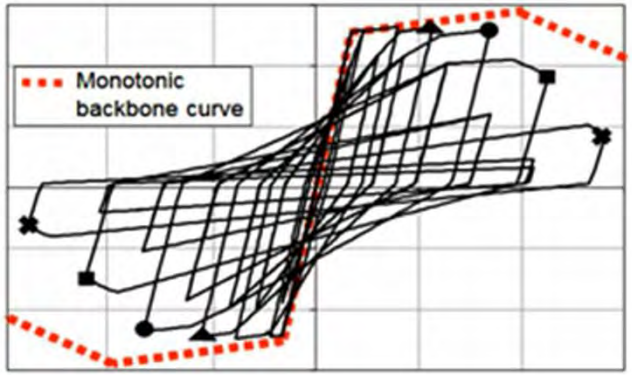


Figure courtesy of MKA

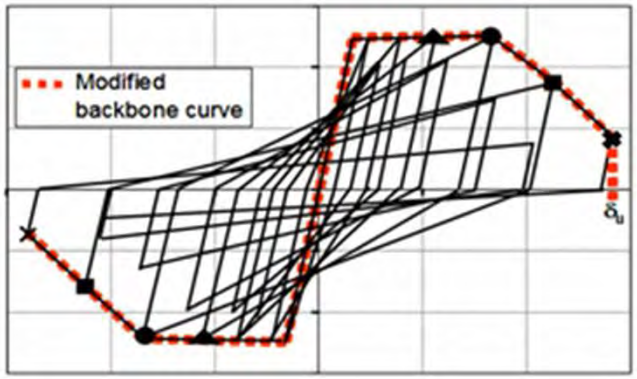
Modeling Strength / Stiffness Degradation

- 2010 PEER TBI
  - Provides detailed guidelines on four approved methods for modeling degradation
- 2014 LATBSDC
  - Adopts the first two of the detailed procedures contained in 2010 PEER.

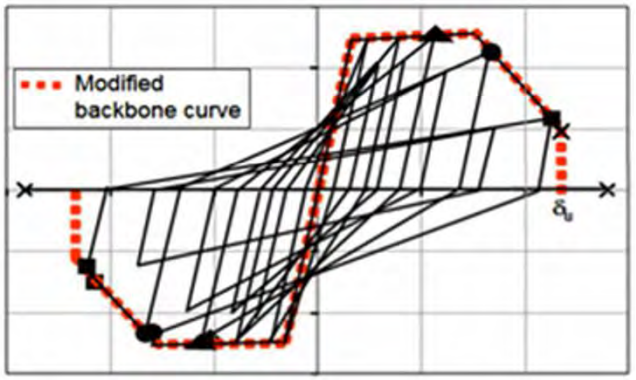
2010 PEER-TBI Degradation Modeling Options



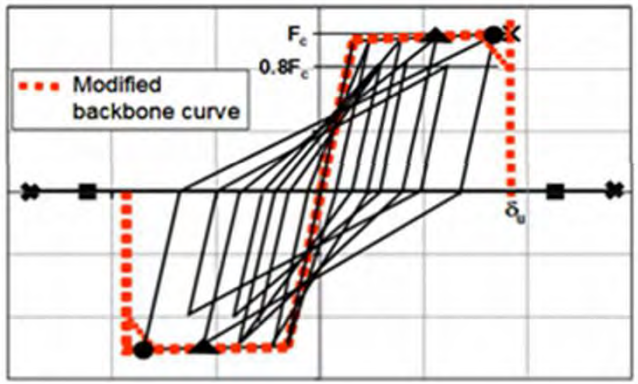
(a) Option 1 – with cyclic deterioration



b) Option 2 – modified backbone curve = envelope curve



(c) Option 3 - modified backbone curve = factored monotonic backbone curve



(d) Option 4 – no strength deterioration

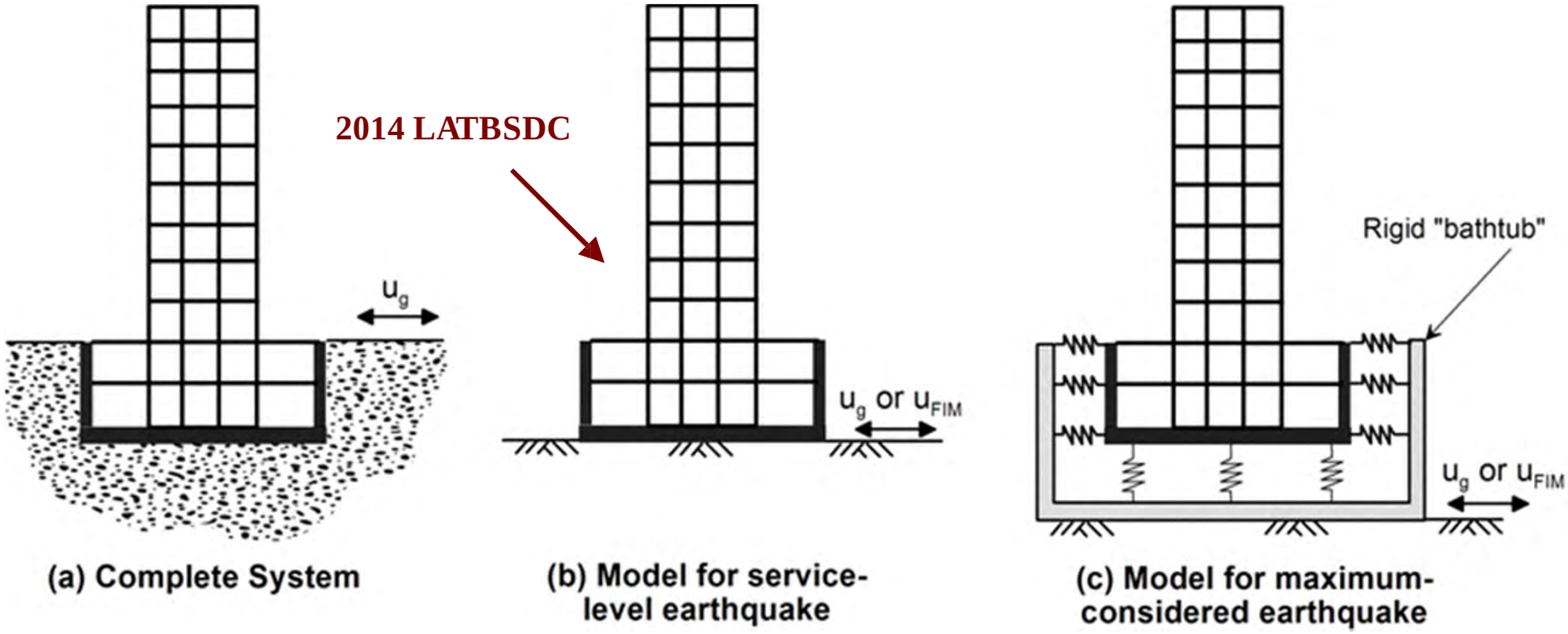
Figure courtesy of Prof. Helmut Krawinkler

Soil-Foundation-Structure-Interaction (SFSI)

- Naeim & Stewart (2008) demonstrated the difficulties of realistic modeling of SFSI in a design environment.
- 2010 PEER-TBI has two recommended modeling techniques
- 2014 LATBSDC recommends a single approach for this.

SFSI

2010 PEER TBI Suggested Modeling Techniques for SFSI



Foundations

- Modeling, Rocking and Uplift:
  - Foundation components that have significant flexibility or will experience significant inelastic behavior shall be modeled following the same approach outlined for components of the superstructure.

Response Modification Devices

- Seismic isolation and energy dissipation devices shall be modeled based on data from laboratory tests representing conditions anticipated during MCE / MCE_R shaking.
- If the properties of these devices vary significantly, lower and upper bound properties shall be modeled.
- The consequences of attaining device limits must be demonstrated to be tolerable to the structure.

Backstay Effects

- 2
- 2

C.3.2.3. Any lower part of a tall building structure that is larger in floor plate, and contains substantially increased seismic-force resistance in comparison to the tower above, can be considered a *podium*. Backstay effects are the transfer of lateral forces from the seismic-force resisting elements in the tower into additional elements that exist within the podium, typically through one or more floor diaphragms. The lateral force resistance in the podium levels, and force transfer through floor diaphragms at these levels, helps a tall building resist seismic overturning forces.

(Illustration from ATC-72)

This component of overturning resistance is referred to as the backstay effect, based on its similarity to the backspan of a cantilever beam. It is also sometimes called "shear reversal" because the shear in the seismic-force resisting elements can change direction within the podium levels. Since the stiffness properties of the elements, particularly diaphragms, are both influential on the seismic design and uncertain, a sensitivity analysis is required. The UB analysis provides an upper-bound estimate of forces in the backstay load path and a

This case will govern the
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below the tower. This
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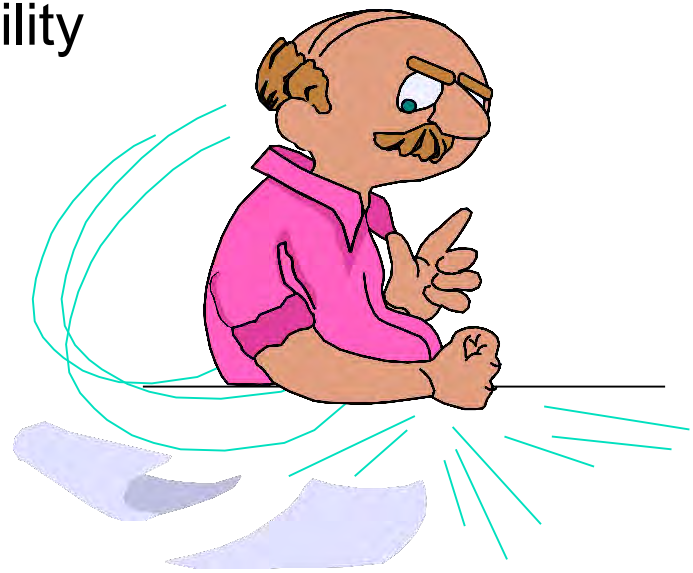
C.3.2.3. Any lower part of a tall building structure that is larger in floor plate, and contains substantially increased seismic-force resistance in comparison to the tower above, can be considered a *podium*. Backstay effects are the transfer of lateral forces from the

Damping

- A particularly thorny issue
  - In nonlinear analyses most of the damping is represented by hysteretic behavior of the elements
  - Some small additional viscous damping may be justified for:
    - Energy dissipation provided by components and systems not explicitly modeled
    - As necessary to avoid numerical instability



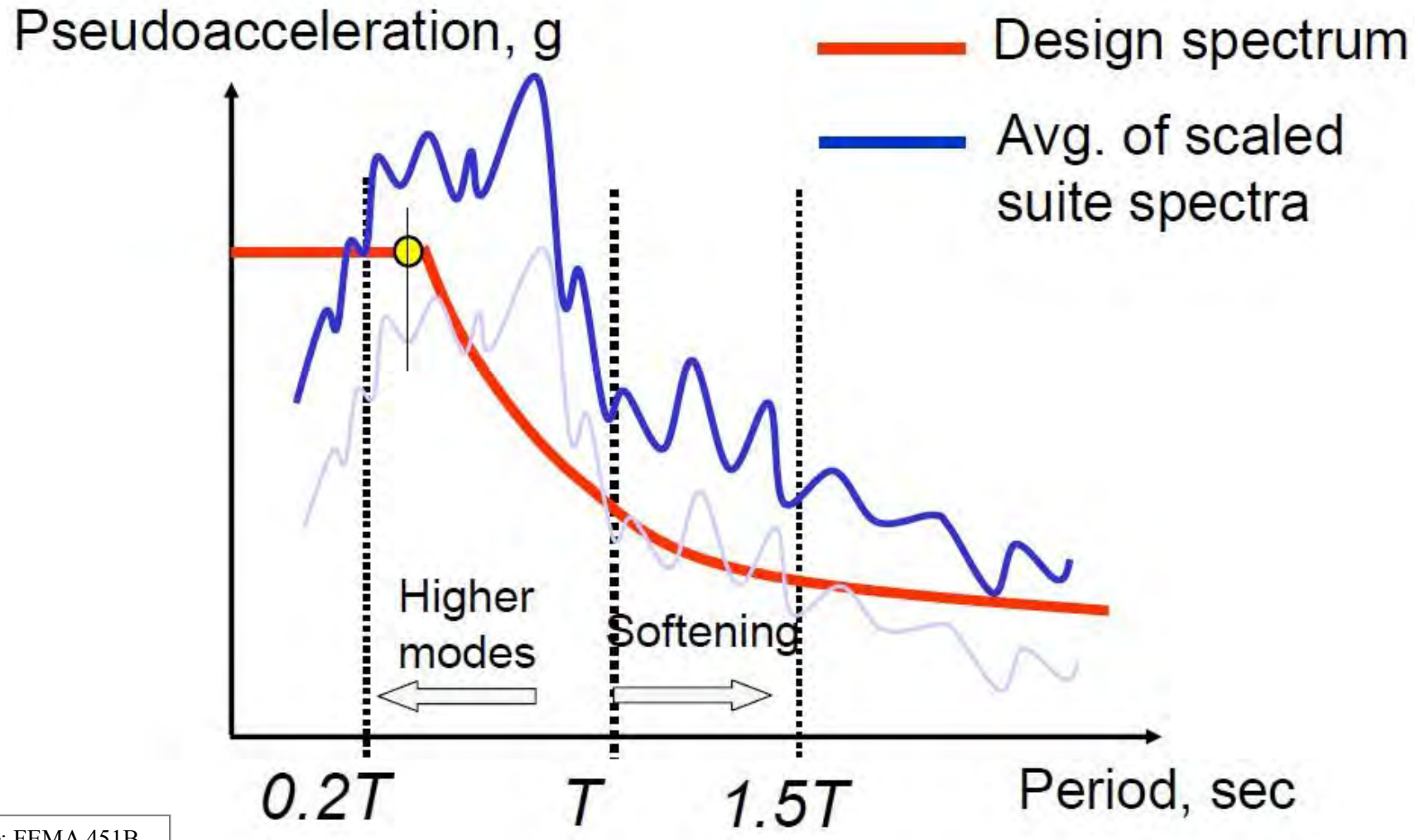
- 2014 LATBSDC
  - Limits viscous damping to 2.5% for both serviceability and MCE.

- 2010 PEER-TBI
  - 2.5% for linear serviceability evaluation
  - Refers to ATC-72 for nonlinear evaluation

Ground Motion Selection and Scaling

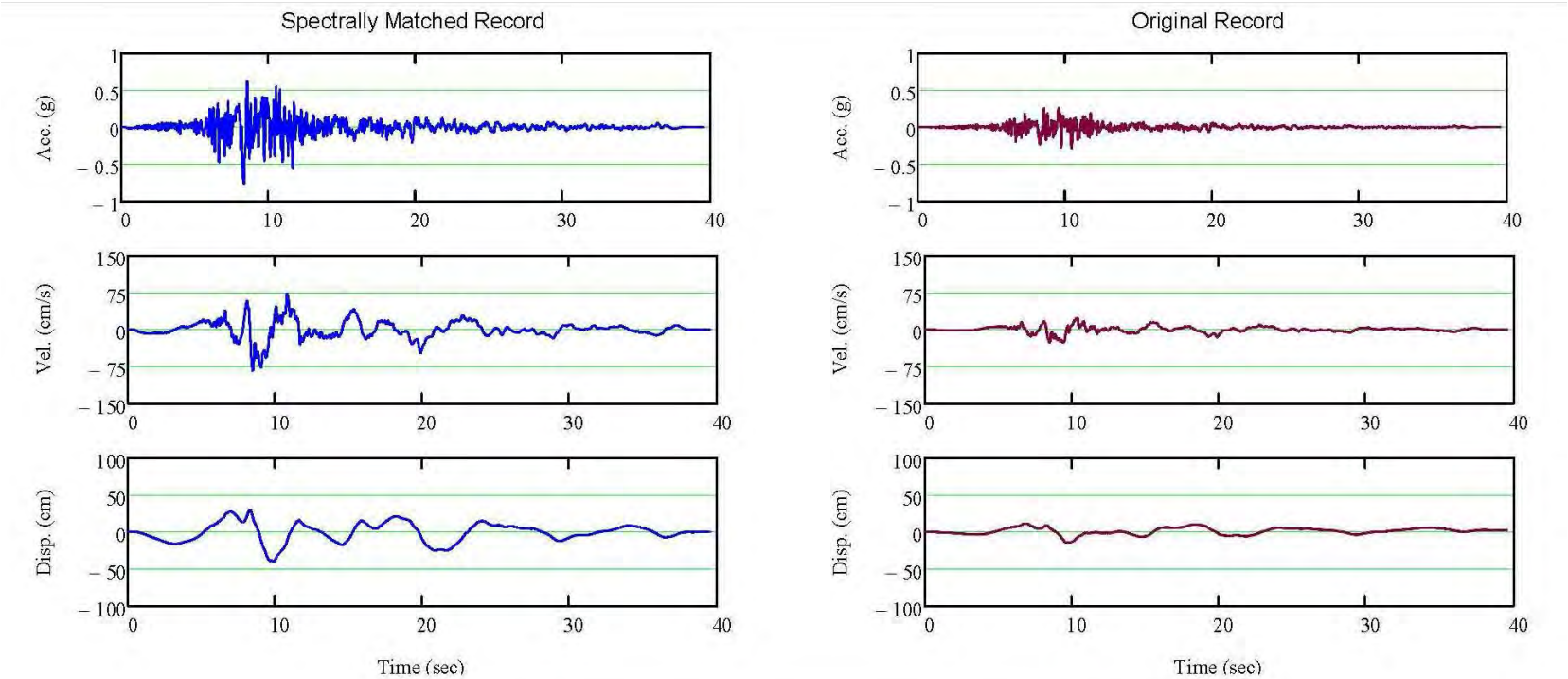
- Three General Methods:
  - Code Scaling in time-domain so that the average of spectra of records stays above design spectrum over a range of periods
  - Spectral Matching by modifying the frequency content of the ground motion
  - Conditional Mean Spectrum (CMS) by scaling at a particular period or periods
- All three methods permitted by both guidelines

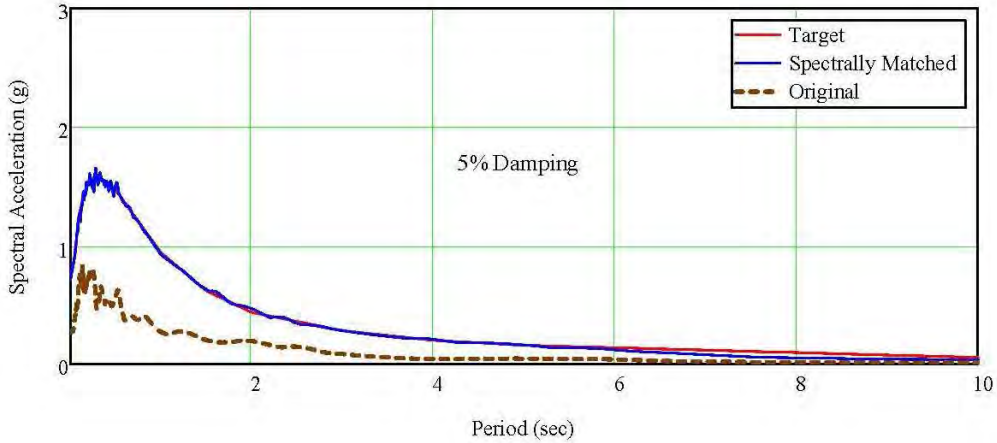
Code Scaling



Source: FEMA 451B

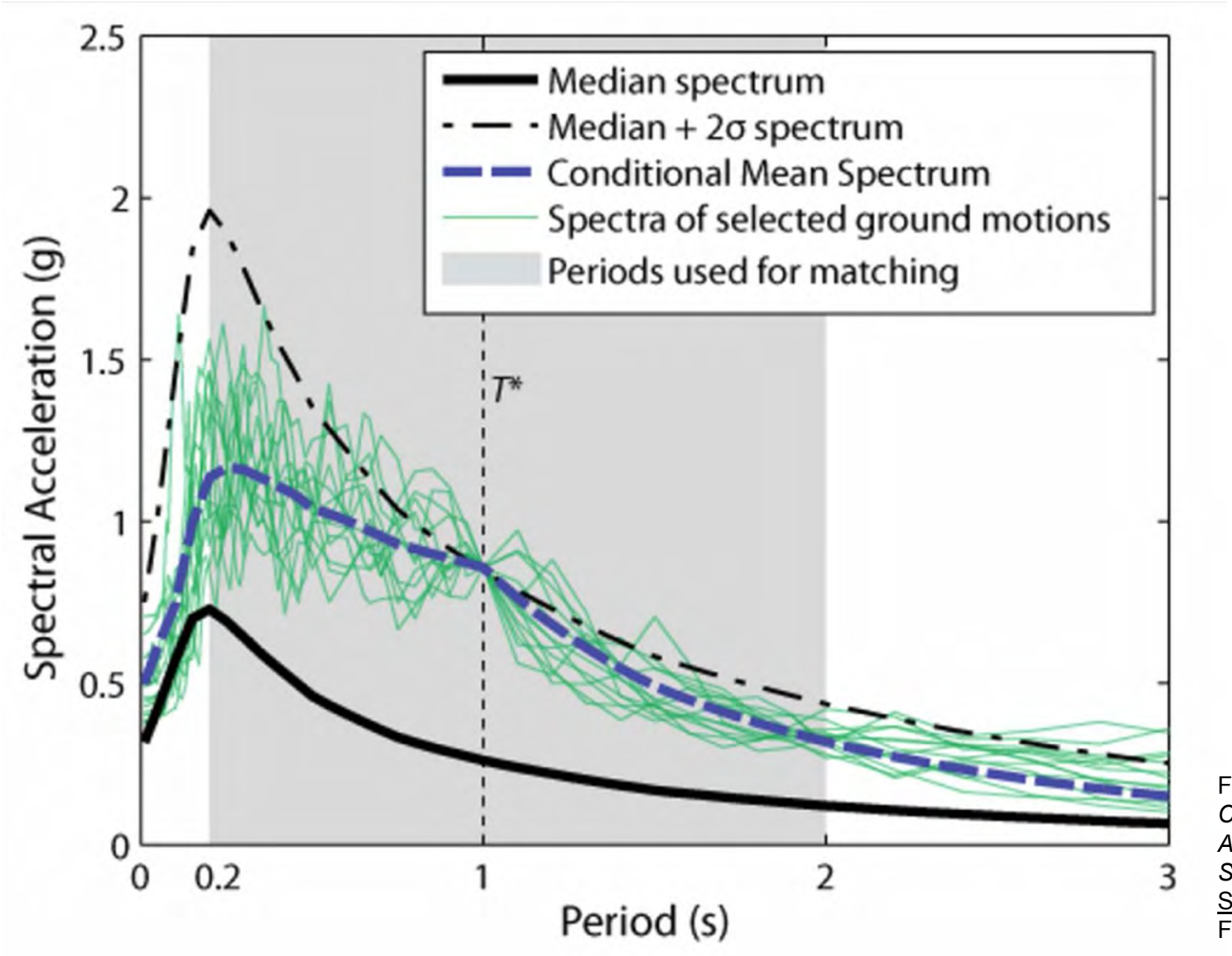
Spectral Matching





Source: Ninyo and More

CMS Scaling



From Jack W. Baker, *The Conditional Mean Spectrum: A Tool for Ground Motion Selection*, ASCE Journal of Structural Engineering, February 2010.

Ground Motion Selection and Scaling

- A minimum of 7 pairs is usually required
- If CMS is used, 2014 LATBSDC requires at least two suites of 7 pairs.
- Attention should be paid to higher modes being addressed by scaling (0.2*T* to 1.5*T*
- Most practicing engineers prefer matching
  - One must be careful as, matched motion contains less record to record dispersion
  - This is one reason 2014 LATBSDC uses 1.5 x mean rather than Mean + x% of SD

2014 LATBSDC R/C Specific Requirements

- Beams in Special R/C Moment Frames
  - In regions where post-yield rotations are expected, the member shall be detailed in the vertical direction as required by ACI 318-11 Eq. (21-5).

2014 LATBSDC R/C Specific Requirements

- High-Strength Concrete

document is defined as concrete with f'_c equal to or greater than 6,000 psi.

3.6.2.1. Intermediate and Specified Strengths

The following concrete compressive strength limits as indicated in Table 7 shall be attained. In addition, the strain attained at the point of maximum strength shall not be less than 0.002 and the strain attained past the point of maximum strength at stress level equal to half of the maximum strength value shall not be less than 0.004 (see Figure 3.6.2.1).

Table 7. Intermediate and final strength values for high-strength concrete

Specified Strength (psi)	Intermediate and final strength values (psi)
$6{,}000 \leq f'_c < 8000$	· 6,000 at 28 days · $1.0 f'_c$ at 90 days
$8{,}000 \leq f'_c \leq 12{,}000$	· 6,000 at 28 days · $0.75 f'_c$ at 90 days · $1.0 f'_c$ at 365 days
$f'_c > 12{,}000$	· $0.50 f'_c$ at 28 days · $0.75 f'_c$ at 90 days · $1.0 f'_c$ at 365 days

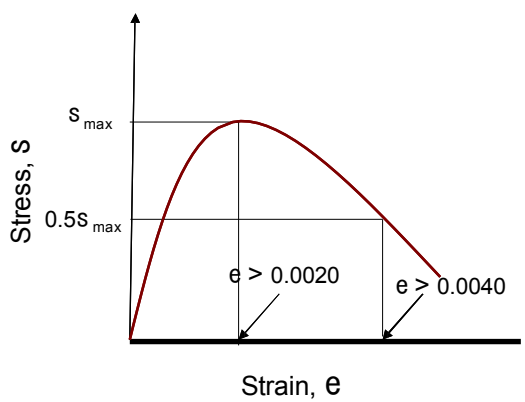
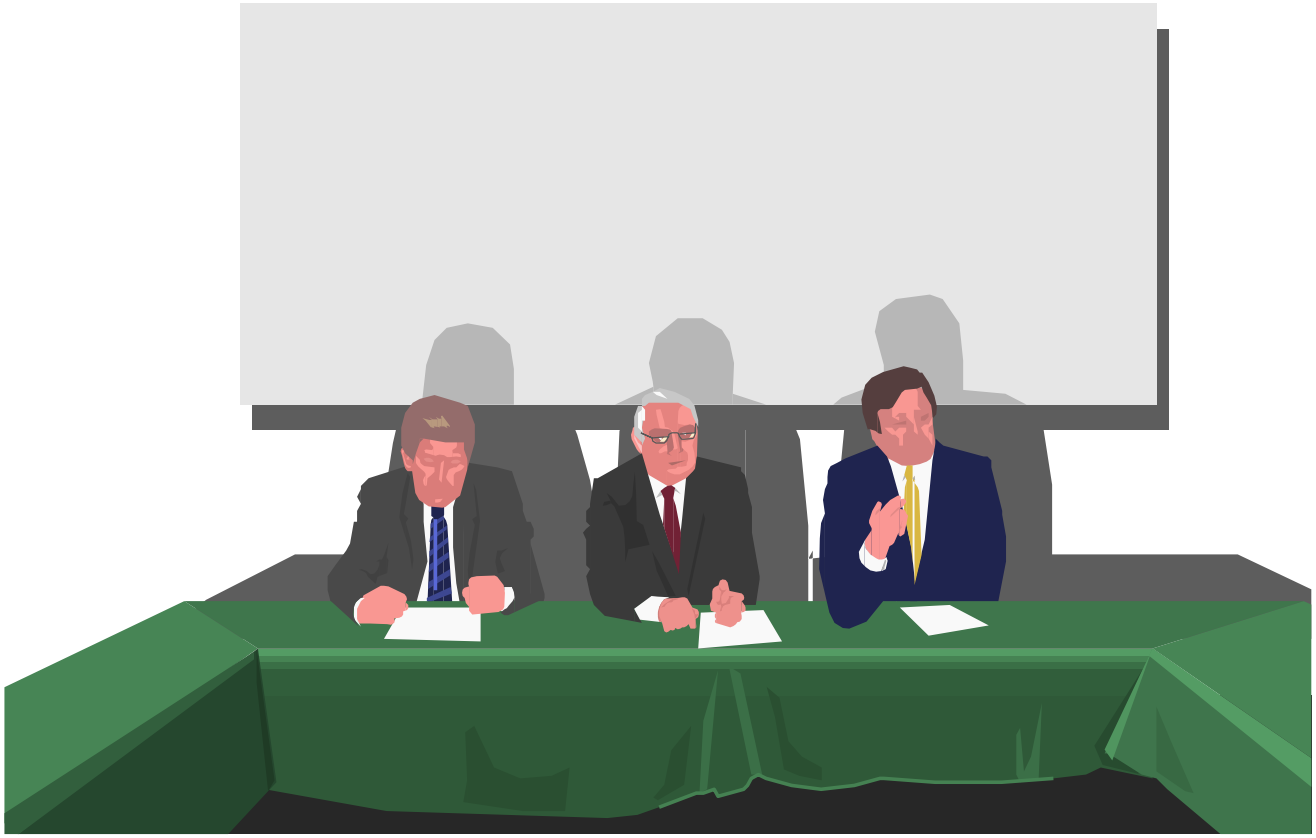


Figure 3.6.2.1. Strain capacity requirements

Peer Review Requirements

- Both documents have extensive peer review requirements which will be discussed in a separate presentation.



Instrumentation Requirements

- 2010 PEER TBI
  - No requirements
- 2011 LATBSDC
  - Detailed requirements
  - Consistent with CGS / CSMIP

Minimum tall building instrumentation levels

Number of Stories Above Ground	Minimum Number of Sensors
10 – 20	15
20 – 30	21
30 – 50	24
> 50	30

LATBSDC Instrumentation Requirements

- Objective:
  - Improve safety and reliability of building systems by providing data to improve computer modeling and enable damage detection for post-event condition assessment
- Plan and Review:
  - An instrumentation plan shall be prepared by the EOR and submitted to SPRP and Building Official for review and approval.
  - SPRP Approved instrumentation plans shall be marked accordingly on the structural drawings.
  - If the building is intended to be included in the inventory of buildings monitored by the California Geologic Survey (CGS) then the recorders and accelerometers must be of a type approved by CGS.

Image courtesy of Mr. John Hooper, MKA

Station selected - Internet Explorer

http://www.strongmotioncenter.org/cgi-bin/CESMD/stationhtml.pl?staID=CE58389&network=CGS

CESMD

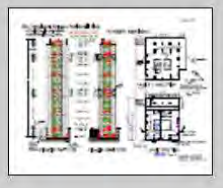
Information for Strong-Motion Station

San Francisco - 62-story Resid. Bldg

CGS - CSMIP Station 58389

Earthquakes recorded by this station

(Station Photograph - click to enlarge)



(Sensor Layout - click to see PDF File)

Latitude	37.7858 N
Longitude	122.3921 W
Elevation (m)	--
Site Geology	
Vs30 (m/sec)	
Site Class	
Remarks	

No. of Stories above/below ground	62/0
Plan Shape	Rectangular
Base Dimensions	137 ft x 113 ft
Typical Floor Dimensions	102 ft x 113 ft
Design Date	2006
Instrumentation	2012, 72 accelerometers on 26 levels.

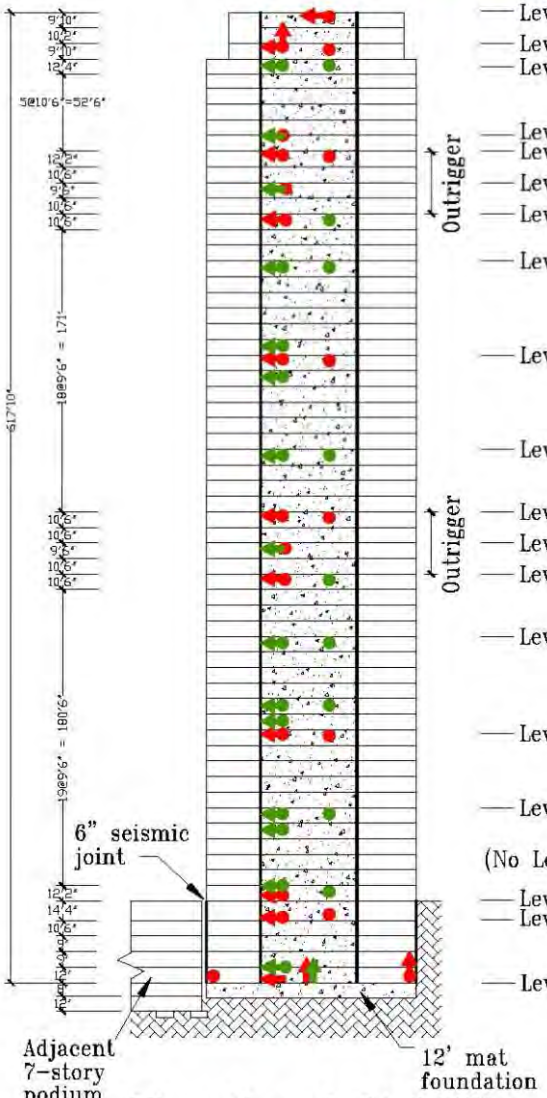
Vertical Load Carrying System	Post-tensioned concrete flat slabs supported by concrete columns and core shear walls.
Lateral Force Resisting System	Concrete core shear walls with supplemental tall outrigger columns of steel reinforced concrete in the transverse direction. The core is attached to outrigger columns by steel buckling restrained braces. Water tanks at the top of the building are part of the "tuned liquid-mass damper" system to reduce wind induced motions.
Foundation Type	Concrete mat foundation (12 feet beneath the tower) bearing on bedrock.
Remarks	This building was instrumented jointly by the California Geological Survey and the U.S. Geological Survey. The building structural design was based on performance-based seismic design.

San Francisco - 62-story Residential Bldg

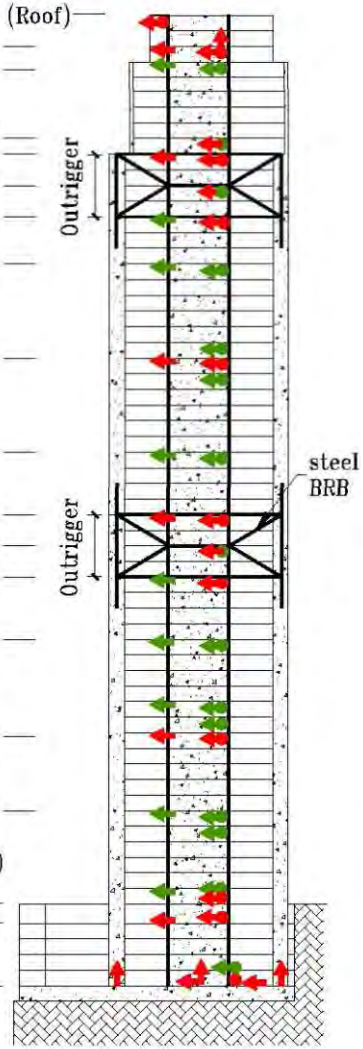
(CSMIP Station No. 58389)
(NSMP Station No. 8389)

CSMIP Sensors (1–36)
NSMP Sensors (37–72)

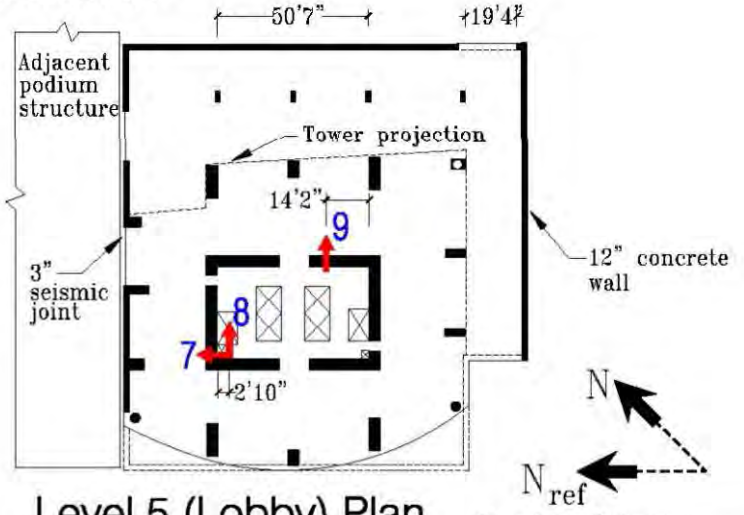
SENSOR LOCATIONS



Elevation A-A' (N/S)

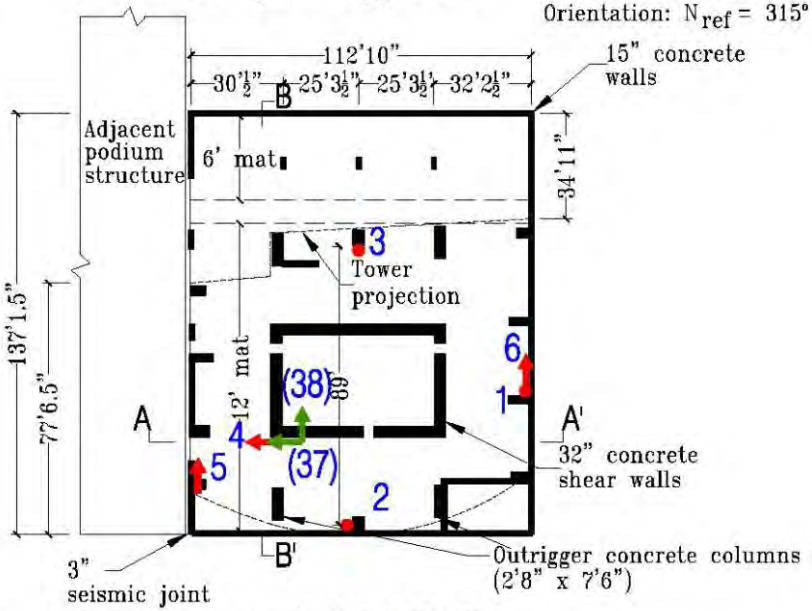


Elevation B-B' (E/W)



Level 5 (Lobby) Plan

Structure Reference Orientation: N_{ref} = 315°



Level 1 (P4) Plan

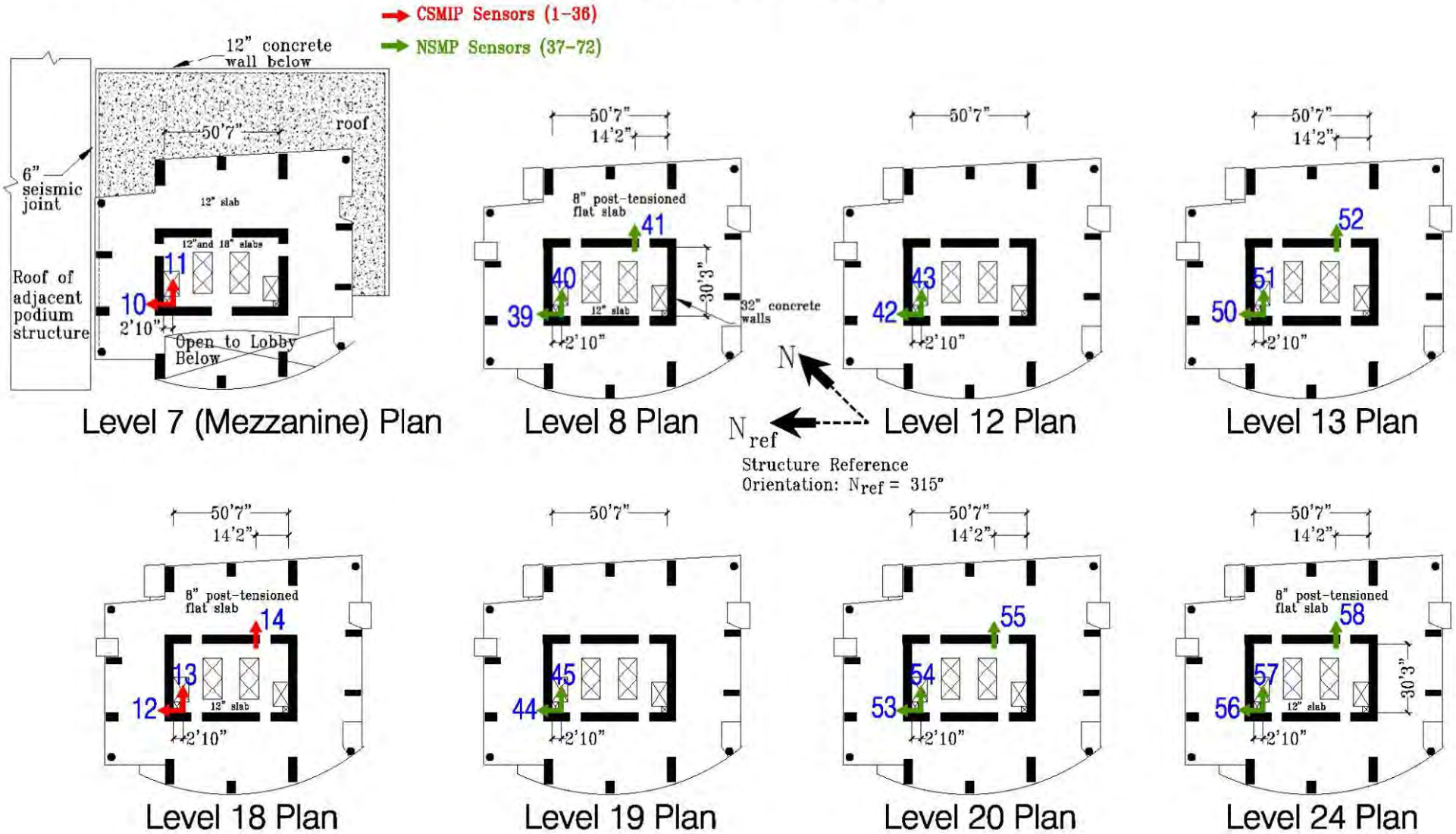
(37) (38) = Level 2

Installed: 5/18/2012
Diagram: 7/11/2013 rev.

San Francisco - 62-story Residential Bldg

(CSMIP Station No. 58389)
(NSMP Station No. 8389)

SENSOR LOCATIONS

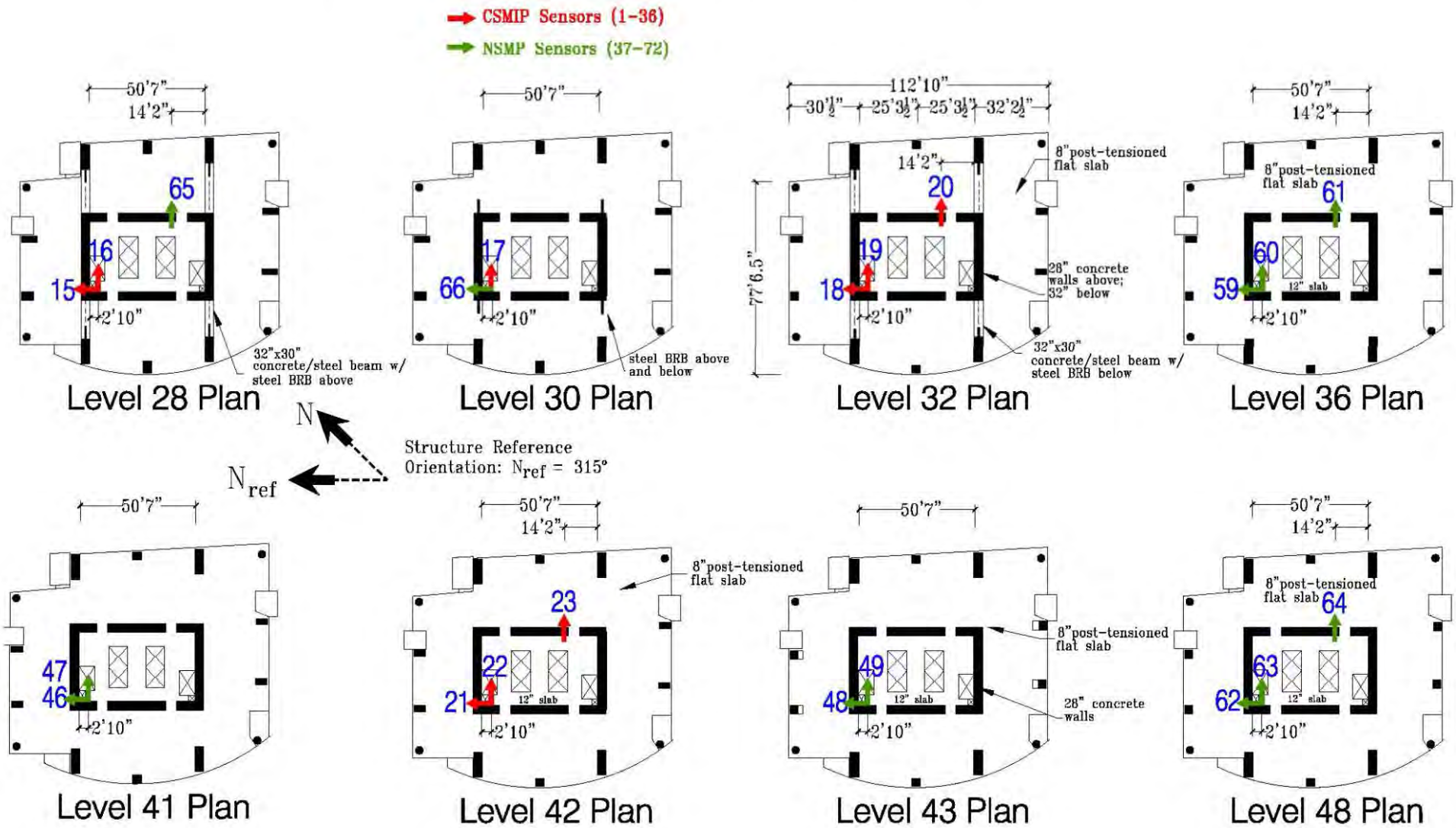


Installed: 5/18/2012
Diagram: 7/11/2013 Rev.

San Francisco - 62-story Residential Bldg

(CSMIP Station No. 58389)
(NSMP Station No. 8389)

SENSOR LOCATIONS



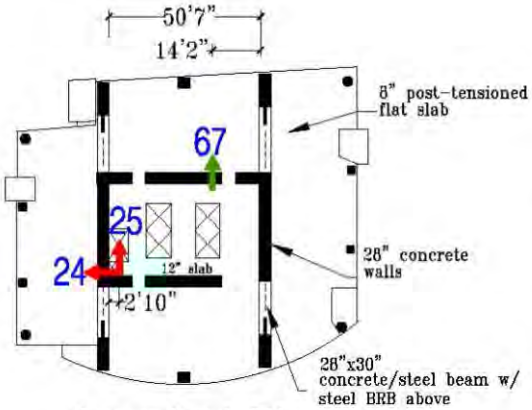
Installed: 5/18/2012
Diagram: 7/11/2013 rev.

San Francisco - 62-story Residential Bldg

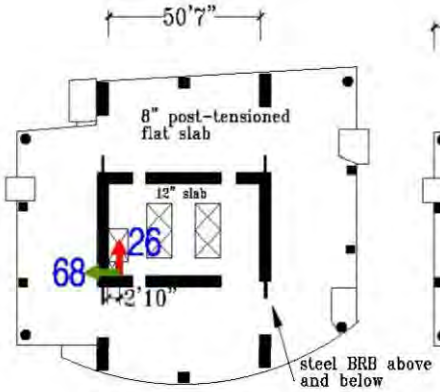
(CSMIP Station No. 58389)
(NSMP Station No. 8389)

SENSOR LOCATIONS

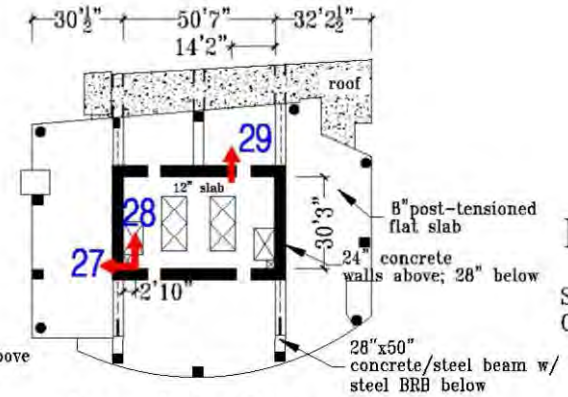
CSMIP Sensors (1-36)
NSMP Sensors (37-72)



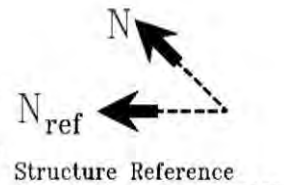
Level 51 Plan

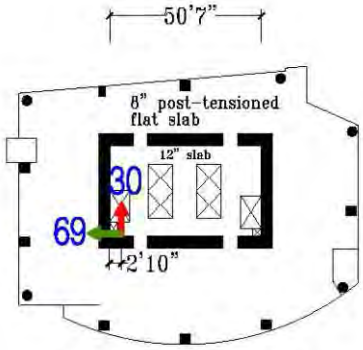


Level 53 Plan

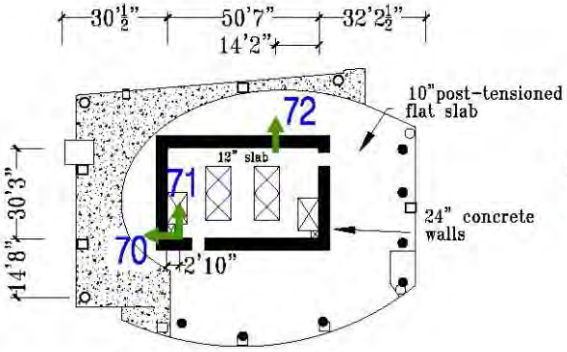


Level 55 Plan

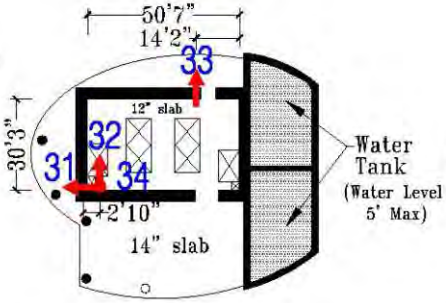




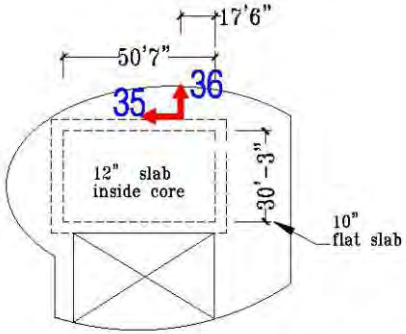
Level 56 Plan



Level 61 Plan



Level 62 Plan



Level 64 (Roof) Plan

Installed: 5/18/2012
Diagram: 7/11/2013

Home | Archive | Search | Station Maps | More Info

CESMD *Internet Quick Report*

American Canyon Earthquake of 24 Aug 2014

6.0ML, 03:20:44 AM PDT, 38.22N 122.31W Depth 11.3 km

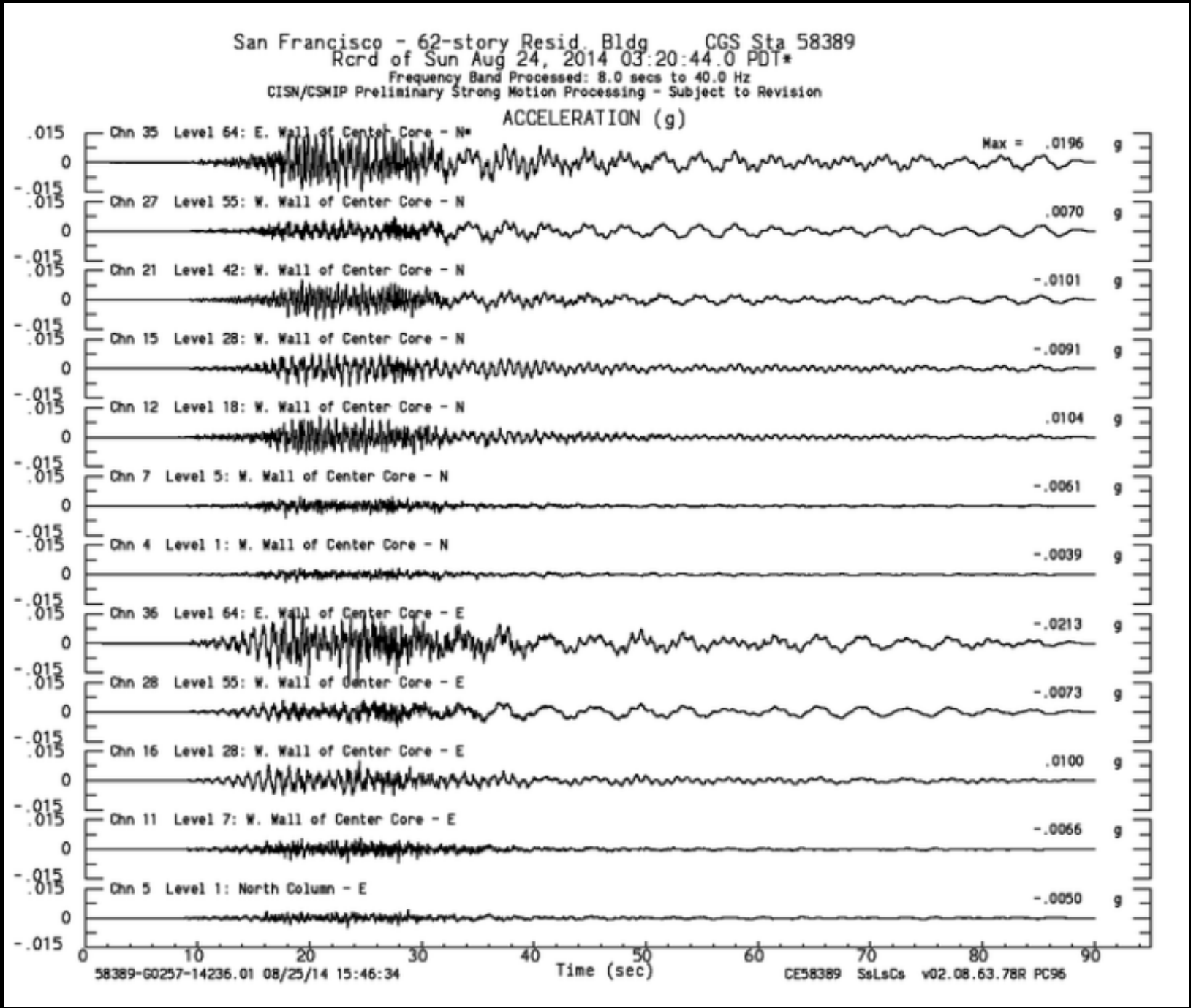
CISN Region of ANSS

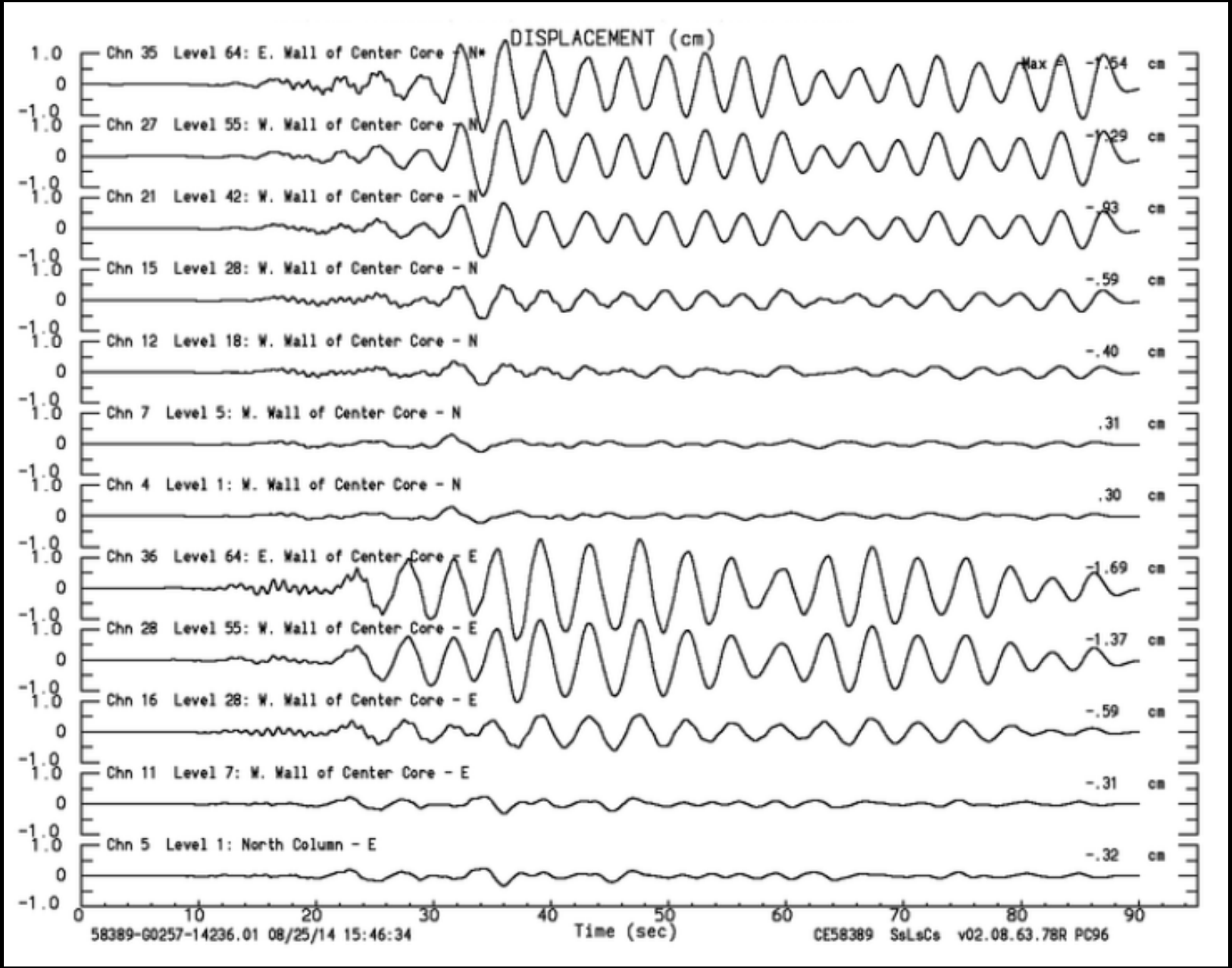
Interactive Map

ShakeMap

Last Update: 2014-08-29 09:02 (Pacific)

Station	Code /ID	Network	Distance (km)		Horiz Apk (g)		View	Download
			Epic.	Fault	Ground	Struct.		
San Francisco - 62-story Resid. Bldg	58389	CGS	48.1	--	**0.005**	0.021	◉	☑


San Francisco - 62-story Resid. Bldg CGS Sta 58389
Rcrd of Sun Aug 24, 2014 03:20:44.0 PDT*
Frequency Band Processed: 8.0 secs to 40.0 Hz
CISN/CSMIP Preliminary Strong Motion Processing - Subject to Revision
ACCELERATION (g)
Chn 35 Level 64: E. Wall of Center Core - N*
Max = .0196 g
Chn 27 Level 55: W. Wall of Center Core - N
.0070 g
Chn 21 Level 42: W. Wall of Center Core - N
-.0101 g
Chn 15 Level 28: W. Wall of Center Core - N
-.0091 g
Chn 12 Level 18: W. Wall of Center Core - N
.0104 g
Chn 7 Level 5: W. Wall of Center Core - N
-.0061 g
Chn 4 Level 1: W. Wall of Center Core - N
-.0039 g
Chn 36 Level 64: E. Wall of Center Core - E
-.0213 g
Chn 28 Level 55: W. Wall of Center Core - E
-.0073 g
Chn 16 Level 28: W. Wall of Center Core - E
.0100 g
Chn 11 Level 7: W. Wall of Center Core - E
-.0066 g
Chn 5 Level 1: North Column - E
-.0050 g
.015
0
-.015
0 10 20 30 40 50 60 70 80 90
Time (sec)
58389-G0257-14236.01 08/25/14 15:46:34
CE58389 SsLsCs v02.08.63.78R PC96


DISPLACEMENT (cm)
Chn 35 Level 64: E. Wall of Center Core - N*
Max = -1.54 cm
Chn 27 Level 55: W. Wall of Center Core - N
-1.29 cm
Chn 21 Level 42: W. Wall of Center Core - N
-.93 cm
Chn 15 Level 28: W. Wall of Center Core - N
-.59 cm
Chn 12 Level 18: W. Wall of Center Core - N
-.40 cm
Chn 7 Level 5: W. Wall of Center Core - N
.31 cm
Chn 4 Level 1: W. Wall of Center Core - N
.30 cm
Chn 36 Level 64: E. Wall of Center Core - E
-1.69 cm
Chn 28 Level 55: W. Wall of Center Core - E
-1.37 cm
Chn 16 Level 28: W. Wall of Center Core - E
-.59 cm
Chn 11 Level 7: W. Wall of Center Core - E
-.31 cm
Chn 5 Level 1: North Column - E
-.32 cm
1.0
0
-1.0
0
10
20
30
40
50
60
70
80
90
Time (sec)
58389-G0257-14236.01 08/25/14 15:46:34
CE58389 SsLsCs v02.08.63.78R PC96

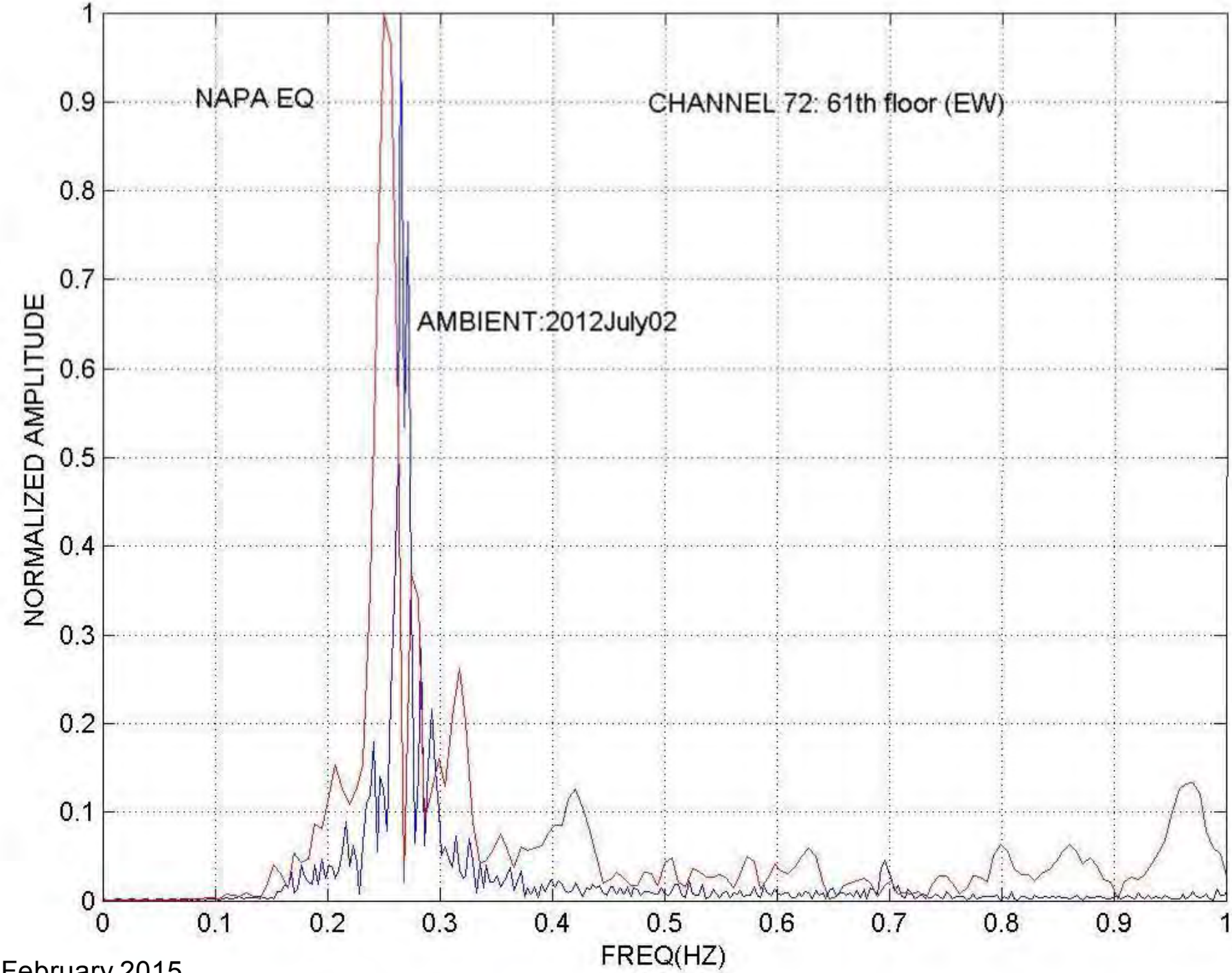
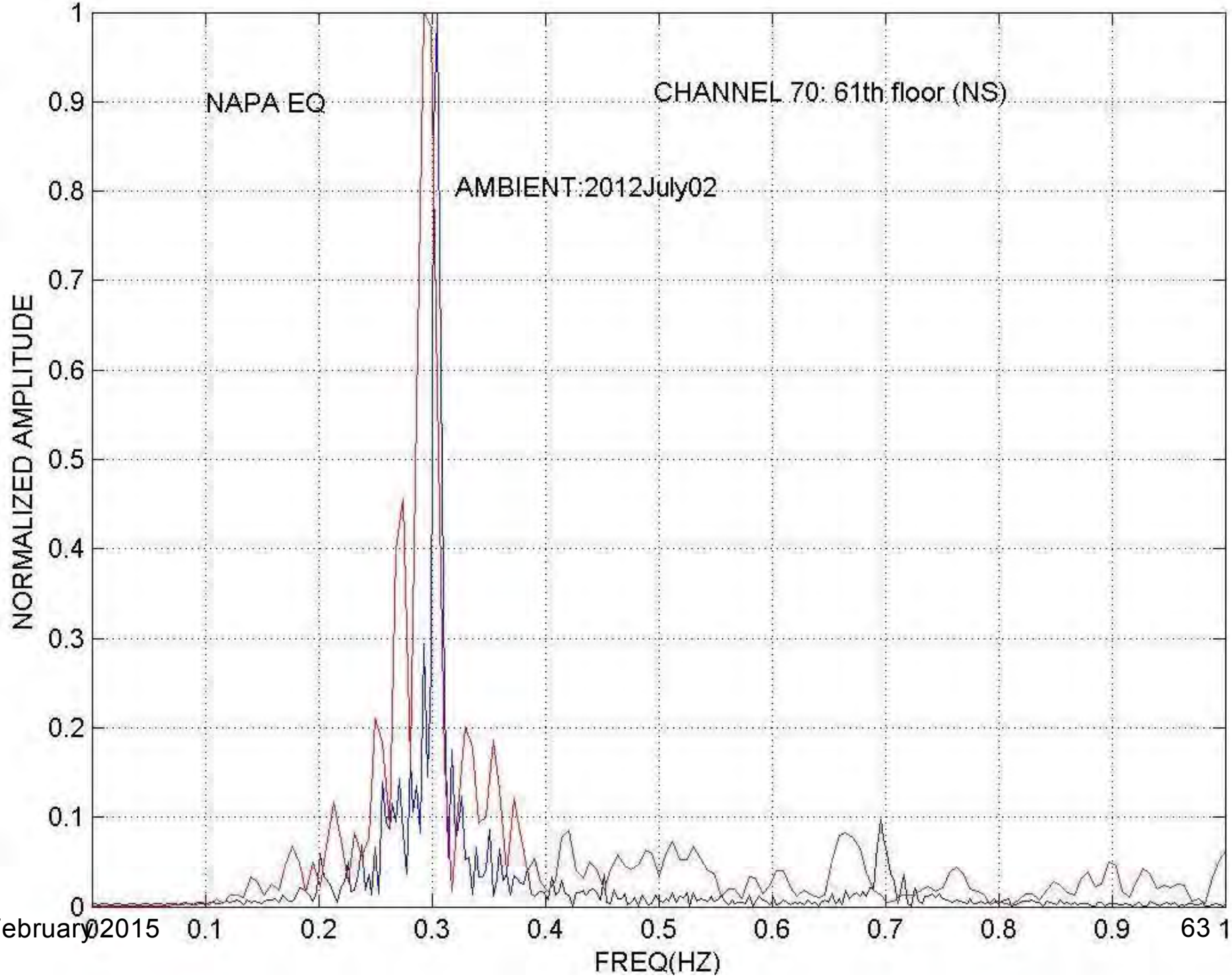


Image courtesy of Mr. John Hooper, MKA


NAPA EQ
CHANNEL 70: 61th floor (NS)
AMBIENT:2012July02
NORMALIZED AMPLITUDE
FREQ(HZ)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Acceptance Criteria

- Key differences to be aware of:
  - Reduction Factors:
    - In 2014 LATBSDC, ϕ = 1.0, always.
    - In 2010 PEER-TBI, ϕ = 1.0 for serviceability; ϕ = code values for MCE
  - Risk Categories:
    - 2014 LATBSDC considers various categories
    - 2010 PEER-TBI assumes Risk Category to be II
  - Modeling Dispersion:
    - 2014 LATBSDC uses 1.5 x mean
    - 2010 PEER-TBI uses 1.5 x mean, or mean + 1.3 x SD > 1.2 x mean, depending on the situation.

Risk Category Reduction Factor

- 2014 LATBSDC

Table 6. Risk Category Reduction Factor

Risk Category from ASCE 7-10 Table 1.5-1	Risk Reduction factor, κ_i
I	1.00
II	1.00
III	0.80
IV	Value to be established by SPRP (see Section 4)

Acceptance Criteria -- Maximum Drift

- Absolute Maximum Transient Drift Angle Limits
  - Serviceability:

    0.005 overall

  - MCE or MCE_R:

    0.030 x K_i max average at any story

    0.045 x K_i max. interstory drift at any story under any record

Acceptance Criteria -- Residual Drift

- Collapse Prevention:

  0.010 x K_i average max. of time histories

  0.015 x K_i maximum from any

Acceptance Criteria

- Strength Loss:
  - In any nonlinear dynamic response analysis, deformation imposed at any story shall not result in a loss of total story strength that exceeds 20% of the initial strength.

Acceptance Criteria -- Serviceability

- 2014 LATBSDC
  - Force-Controlled Actions:

    Strength Demand $\leq$ 0.7 x Capacity
  - Deformation-Controlled Actions:
    - Response Spectrum Analysis
      - Strength Demand $\leq$ 1.50 x Capacity, (Risk Category I, II)
      - Strength Demand $\leq$ 1.20 x Capacity, (Risk Category III)
      - Talk to SPRP for Risk Category > III
    - Nonlinear Analysis
      - Can use up to IO limit of ASCE 41

Acceptance Criteria -- MCE

- 2010 PEER
  - Force-Controlled Actions:
    - Two Groups:
      - Critical Actions
        - » failure mode pose severe consequences to structural stability under gravity and/or lateral loads
        - » Design for mean + 1.3 to 1.5 times SD
        - » Use code reduction factors, ϕ = 0.75 for shear
      - Noncritical Actions
        - » Design for mean demand values and ϕ = 1.0.
- 2011 LATBSDC
  - Essentially the same, except uses 1.5 times mean, ϕ = 1.0, and a factor for risk category.

Acceptance Criteria -- MCE

- Force-Controlled Actions:
  - Critical Actions:

3.5.4.1 Force-Controlled Actions

(a) Critical Actions

2014 LATBSDC

Force-controlled critical actions are those force-controlled actions whose mode poses severe consequences to structural stability under gravity and/or lateral loads. Force-controlled critical actions shall satisfy:

$$F_{uc} \pounds k_i f F_{n,e}$$

where

Different in PEER-TBI → F_{uc} = 1.5 times the mean value of demand.

$F_{n,e}$ = nominal strength as computed from applicable material codes but based on expected material properties.

Different in PEER-TBI → f = 1.0.

Different in PEER-TBI → k_i = Risk reduction factor given in Table 6.

EXCEPTION: For buildings located in the Los Angeles region if the serviceability acceptance criteria are satisfied per requirements of Section 3.4.5.1, then k_i may be taken as 1.0.

C.3.5.4.1.1(a) Use of the mean value would imply a significant probability of failure with associated consequences. The use of mean plus one standard deviation is more appropriate. However, when fewer than 20 ground motion pairs are used in nonlinear dynamic response analysis, little confidence can be placed in the computed value of the standard deviation or the mean. A factor of 1.5 is utilized to represent a simple yet reasonable means to reduce

Acceptance Criteria -- MCE

- Force-Controlled Actions:
  - Non-Critical Actions:

2014 LATBSDC

Non-Critical Actions

Noncritical actions are those force-controlled actions for which failure does not result in structural instability or potentially life-threatening damage such as diaphragm shear and axial forces in diaphragm chords and drag members as well as foundation forces.

Force-controlled noncritical actions shall satisfy:

$$F_u \leq k_i f F_{n,e}$$

where

F_u = the mean demand obtained from the suite of analyses,

$F_{n,e}$ = nominal strength as computed from applicable material codes but based on expected material properties.

f = 1.0.

Different in PEER-TBI → k_i = Risk reduction factor given in Table 6.

EXCEPTION: For buildings located in the Los Angeles region if the serviceability acceptance criteria are satisfied per requirements of Section 3.4.5.1, then k_i may be taken as 1.0.

threatening damage, use of mean demand values are justified. Please note that degradation and loss of story strength are limited by other provisions contained in this document.

Upper Limit on Column Axial Forces

- Large axial forces reduce available R/C column ductility

- 2014 LATBSDC
  - MCE: $P \leq 0.4f'_c A_g$

- 2010 PEER-TBI
  - MCE: P < balanced load

    $\leq 0.3f'_c A_g$

Acceptance Criteria -- MCE

- Deformation-Controlled Actions:

2014 LATBSDC

  - $\leq K_i$ x Primary CP limits in ASCE-41
  - Larger values may be used only if substantiated by appropriate laboratory tests.
  - If exceeded, strength degradation, stiffness degradation and hysteretic pinching shall be considered and base shear capacity of the structure shall not fall below 90% of the base shear capacity at deformations corresponding to ASCE 41Primary CP limits

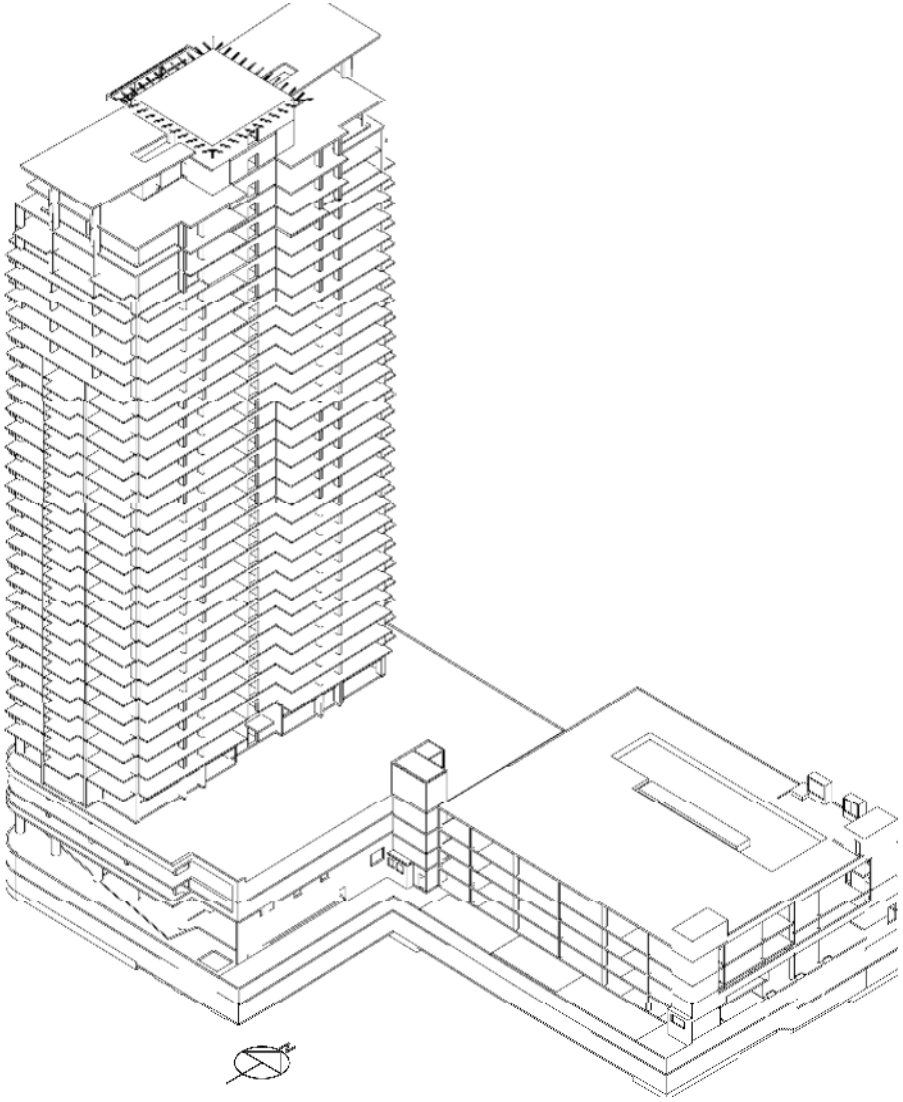
  – 2010 PEER-TBI is not as rigid and refers to ASCE 41 as a source of information.

APPLICATION EXAMPLES

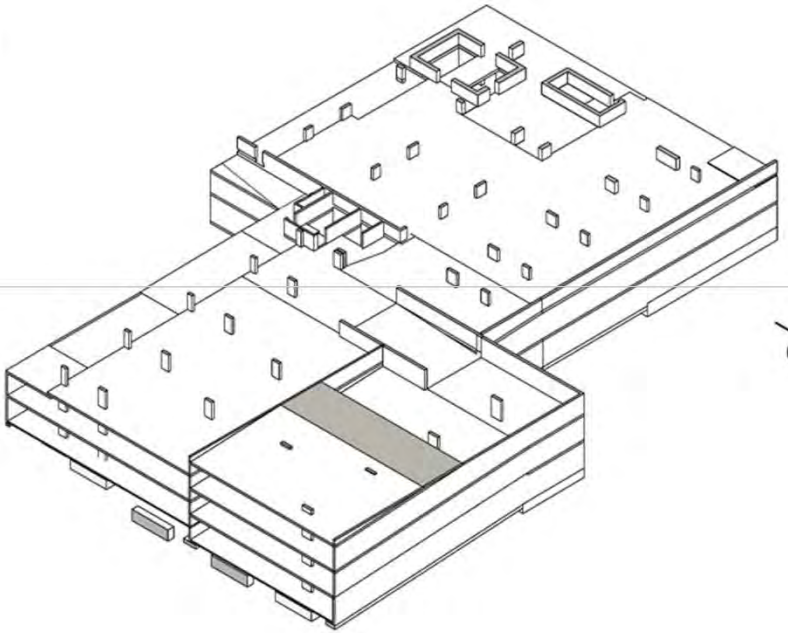
Applications

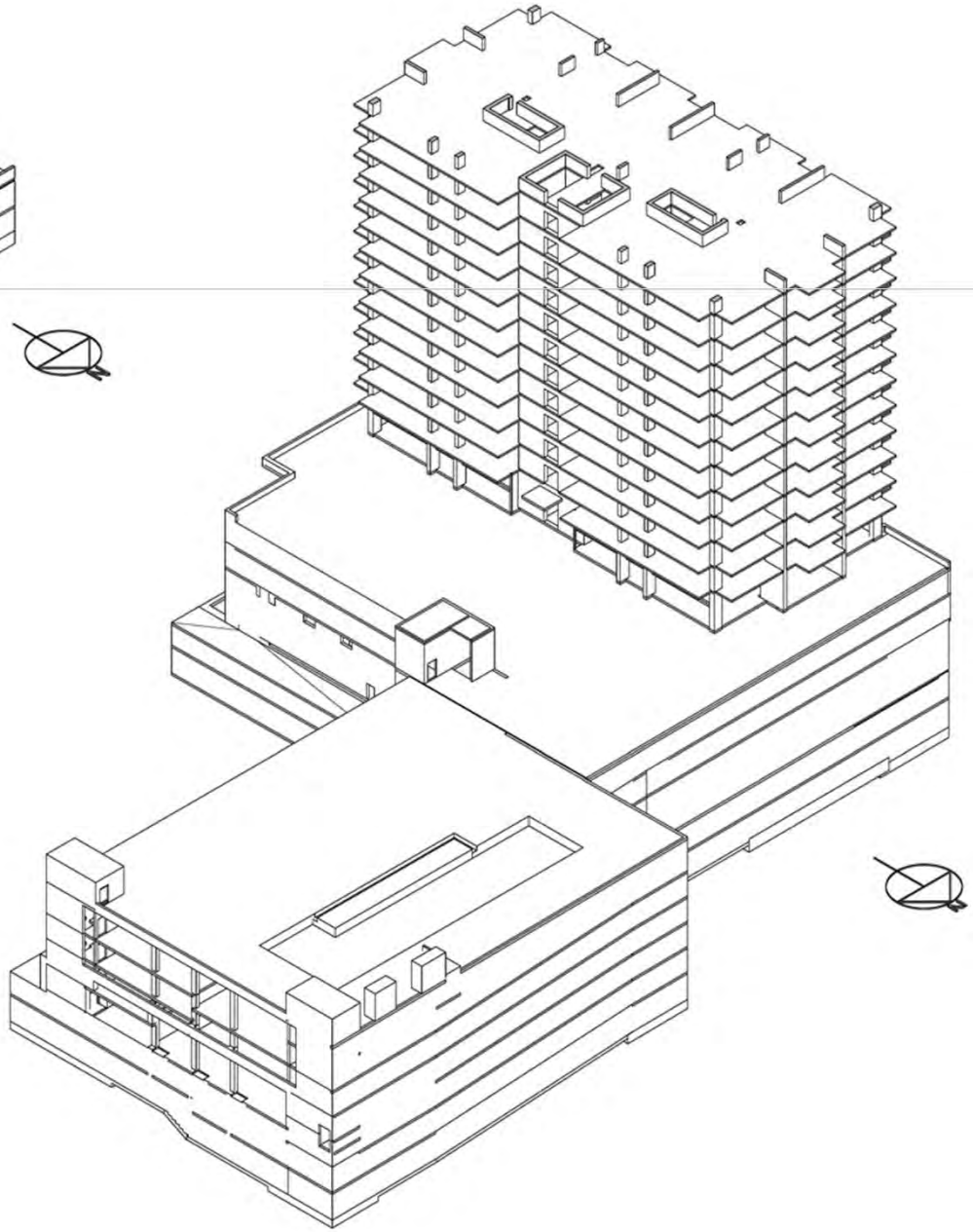
- Many tall buildings have been designed using these guidelines in Los Angeles, San Francisco, San Diego, and elsewhere
- Here are some examples
  - Los Angeles:
    - 888 Olive
    - 1133 Olive
    - 1212 Flower Towers
    - Wilshire & Grand
    - Metropolis Tower
  - San Diego
    - 7th & Ash
  - San Francisco
    - Transbay Tower

- 888 Olive Street in downtown Los Angeles
  - 34 stories
  - Core wall construction
  - Podium
  - Subterranean levels
  - Basement walls
  - Flat plates
  - Gravity columns

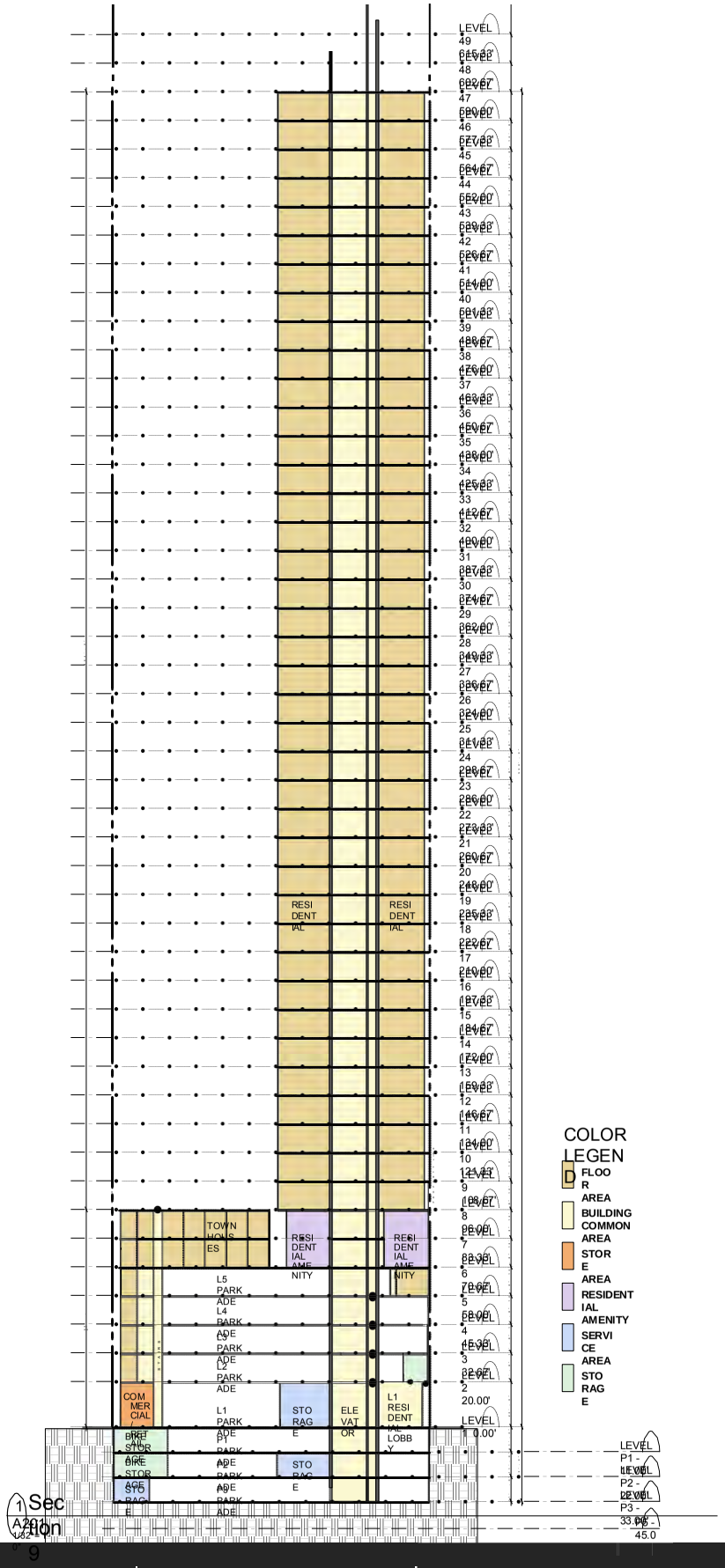


Illustrations and drawings courtesy of Onni Group and Glotman-Simpson





Illustrations and drawings courtesy of Onni Group and Glotman-Simpson



1 Section
A201
1/32" = 1'-0"

CHRIS DIKEAKOS

OLIVE ST. MIXED-USE DEVELOPMENT

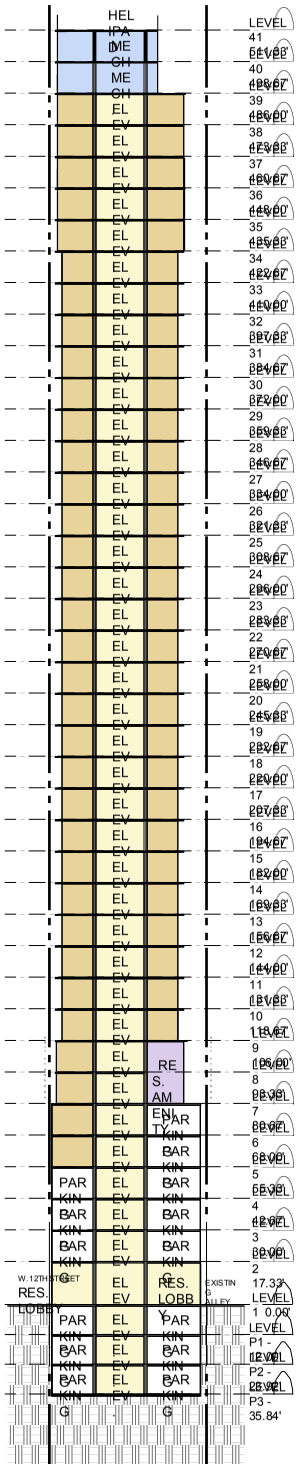
SECTION

SCALE: 1/32" = 1'-0"

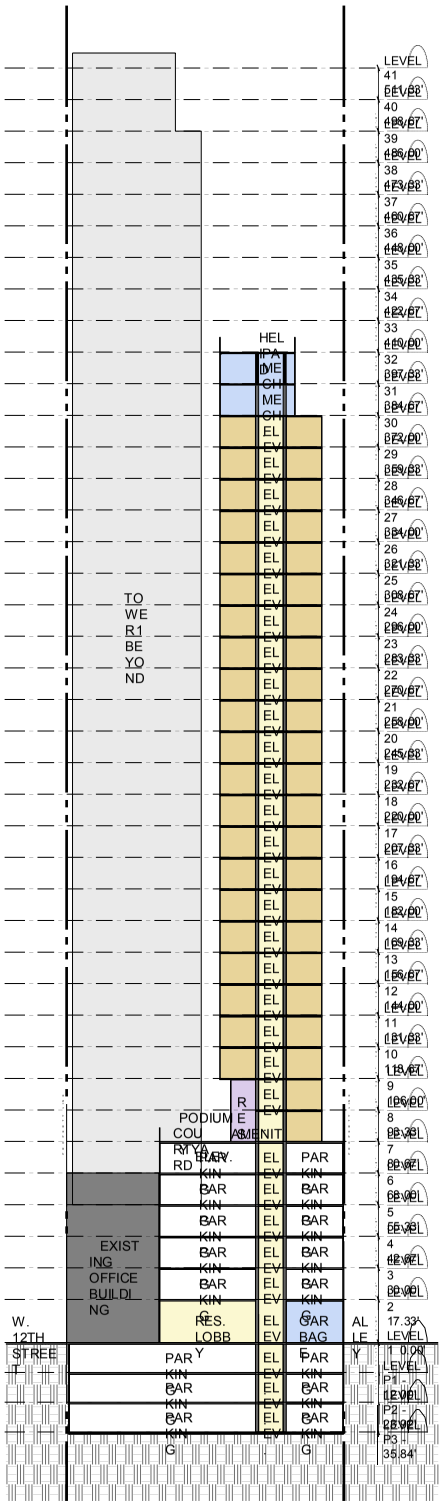
Design Development

A3

February 2015



2 TOWER1 BUILDING SECTION
A201 1/32"=1'-0"



1 TOWER2 BUILDING SECTION
A201 1/32"=1'-0"

CHRIS DIKEAKOS

FLOWER ST. MIXED-USE DEVELOPMENT

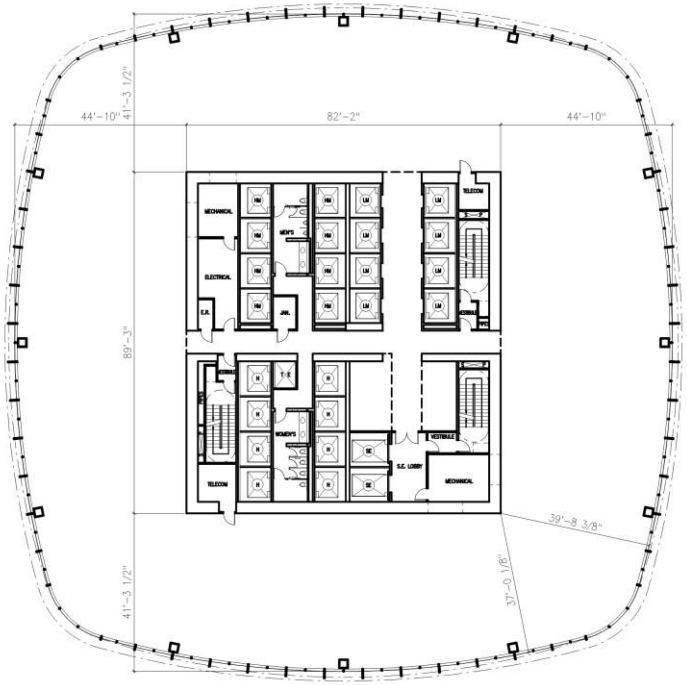
BUILDING SECTIO

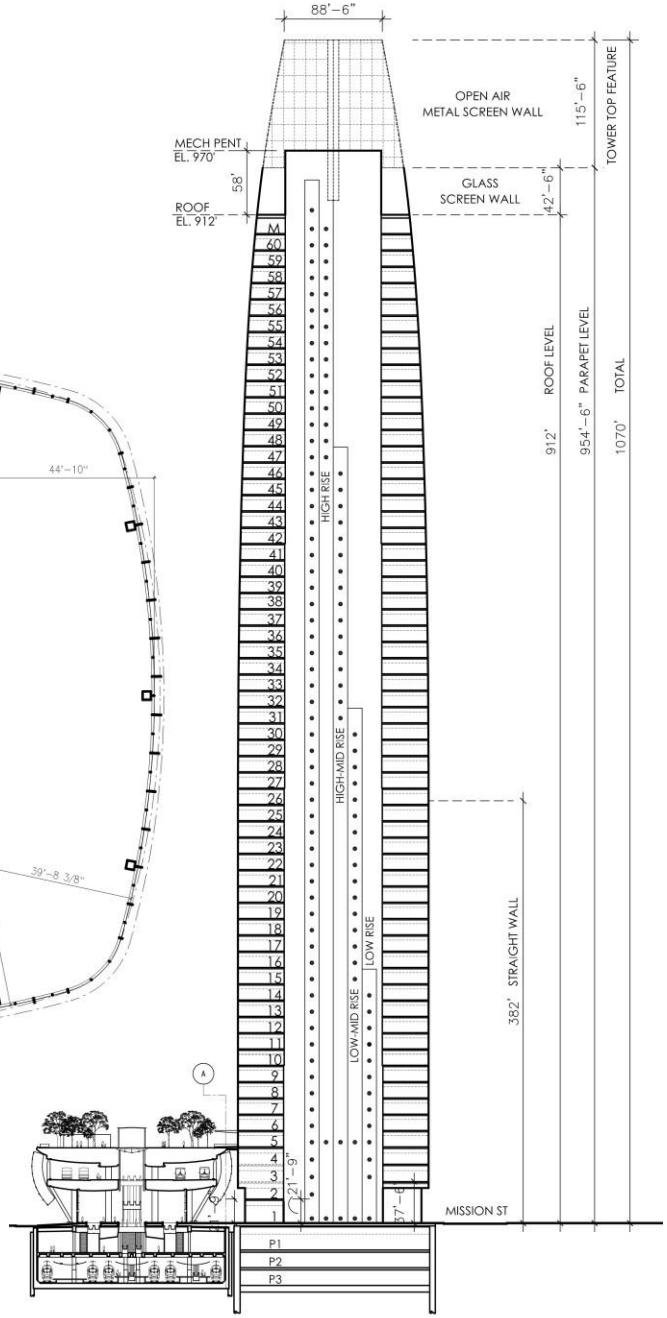
DESIGN DEVELOPMENT

onni group

A 3

February 2015





February 2015

Thank you!