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Current Trends in Performance Based Wind and Seismic Design for Tall Buildings

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Preliminaries

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<u>Audience may or may not have experience with:</u>

- Performance Based Design (PBD)
- Time history (demand vs time) analysis
- Nonlinear analysis (static and dynamic)

<u>Learning Objectives:</u>

1. Name the two primary reference guidelines presented for performance-based wind and seismic design.
2. Summarize the differences between force and deformation-controlled element actions.
3. Identify the PBD structural analysis modeling features that require special consideration.

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1. Prescriptive Design

Codes, Standards, Guidelines

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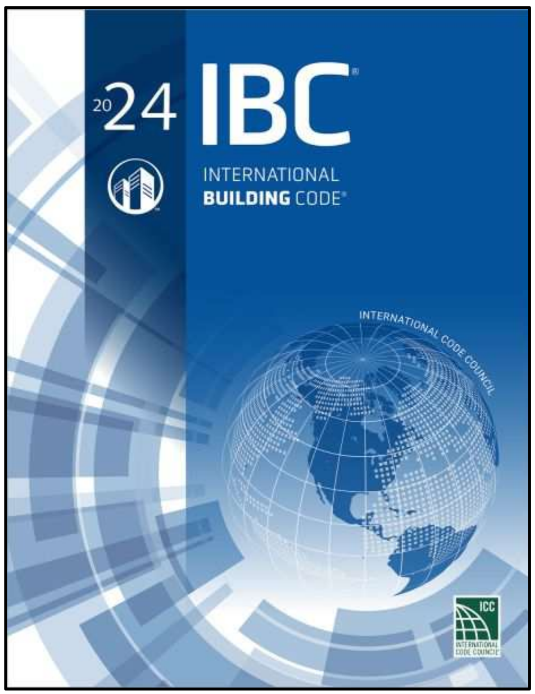
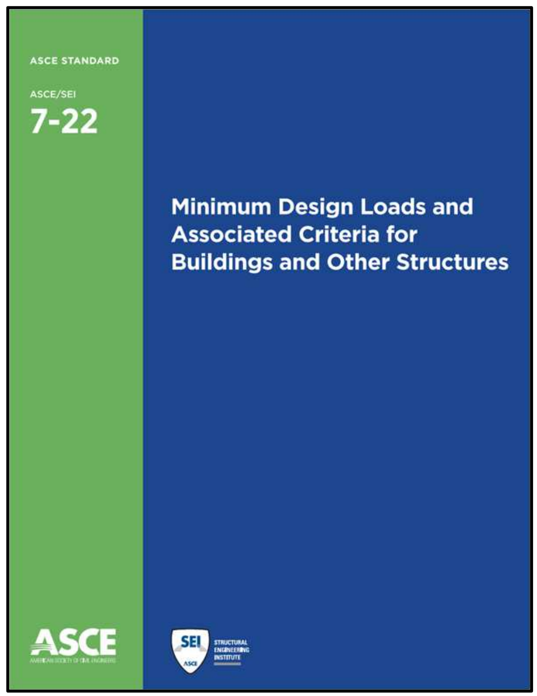
<u>The Hierarchy of US Codes and Standards</u>

- States adopt IBC edition with amendments
- Local jurisdiction amendments (e.g., the Seattle Building Code)

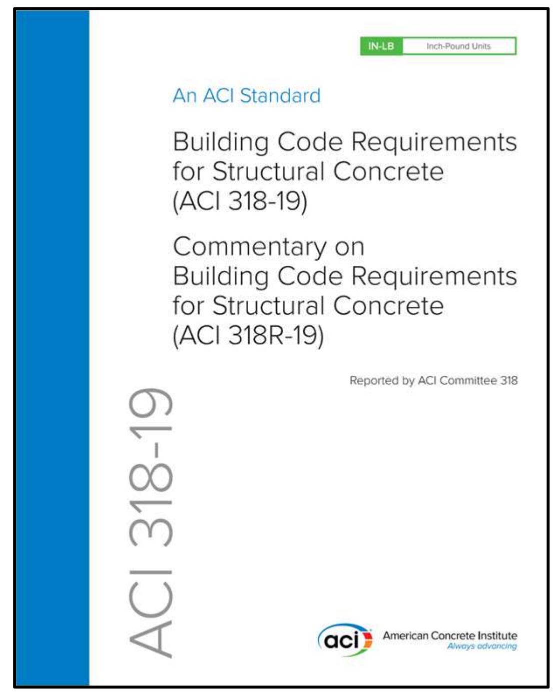
<u>2024 IBC</u>



<u>ASCE 7-22</u>



<u>ACI 318-19</u>



Codes, Standards, Guidelines

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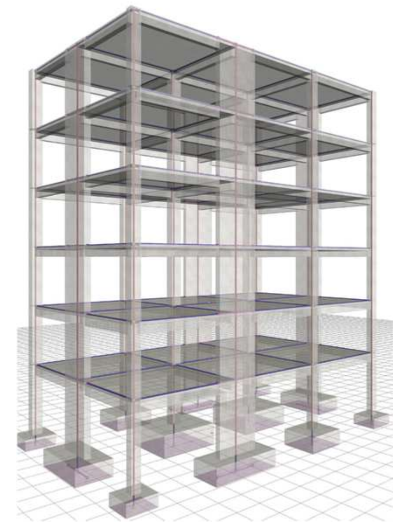

Why PBSD?

- Overcome height limits in ASCE 7 12.2-1
- Freedom in structural configuration: e.g., Dual System not required
- Enhanced and predictable performance

The Upfront Cost of Performance Based Design

- Additional engineering time
- Increased analytic computation and post-processing time
- Peer review

Table 12.2-1. Design Coefficients and Factors for Seismic Force-Resisting Systems.

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, Ω_0^b	Deflection Amplification Factor, C_d^c	Structural System Limitations Including Structural Height, h_n, Limits (ft)[d] — Seismic Design Category: B	C	D^e	E^e	F^f
A. BEARING WALL SYSTEMS									
1. Special reinforced concrete shear walls[g,h]	14.2	5	2½	5	NL	NL	160	160	100
2. Reinforced concrete ductile coupled walls[g]	14.2	8	2½	8	NL	NL	160	160	100
3. Ordinary reinforced concrete shear walls[g]	14.2	4	2½	4	NL	NL	NP	NP	NP

Rumor Has it: The SRCSW 160-foot height limit based on the height of a courthouse in Los Angeles.

Codes, Standards, Guidelines

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How is a PBS(D/W) permitted? Example from a project Basis of Design:

The design will utilize a performance-based procedure as allowed in Section 1604.4 of the IBC and Section 12.2.1 of ASCE 7.

> **1604.4 Analysis:** "Any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics. Such analysis shall result in a system that provides a complete load path capable of transferring loads from their point of origin to the load-resisting elements."
>
> **12.2.1 Structural System Selection and Limitations:** "...Seismic force-resisting systems that are not contained in Table 12.2-1 are permitted if analytical and test data are submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to the structural systems listed in Table 12.2-1 for equivalent response modification coefficient, R, system overstrength coefficient, Ω_0, and deflection amplification factor, C_d, values."

The design is also intended to meet the performance-based equivalence criteria of Section 104.11 of the IBC:

> **104.11 Alternative Materials, Design and Methods of Construction and Equipment:** "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. Any alternative material, design, or method of construction shall be approved where the building official finds 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."

Seismic vs Wind Design

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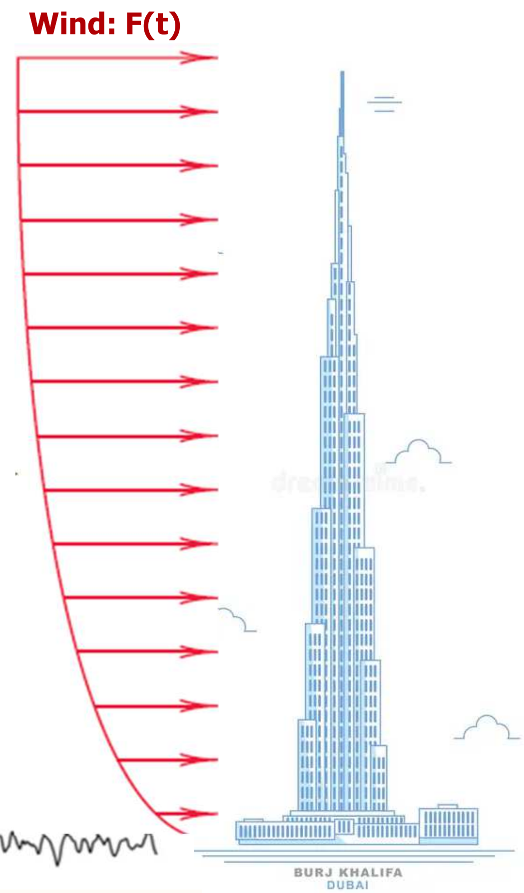
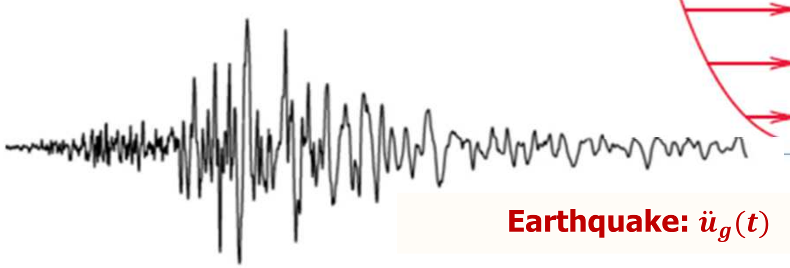
Loading Mechanism

NB: A "Time History" is the variation of wind force or ground acceleration vs time.





Credit: Dreamstime.com

Response Determination

Static: $F = kx$

Dynamic

Earthquake: $m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g$

Wind: $m\ddot{u} + c\dot{u} + ku = F(t)$

Prescriptive (Code) Design Process

1. Determine hazard and loading
2. Analyze structure for element force and global deformation demands
3. Size elements
4. Check seismic "drift" (deformation) per story (*)
5. Design structural elements (size & detail)
6. Done

** No code prescriped wind deformation limits*

Seismic vs Wind Design

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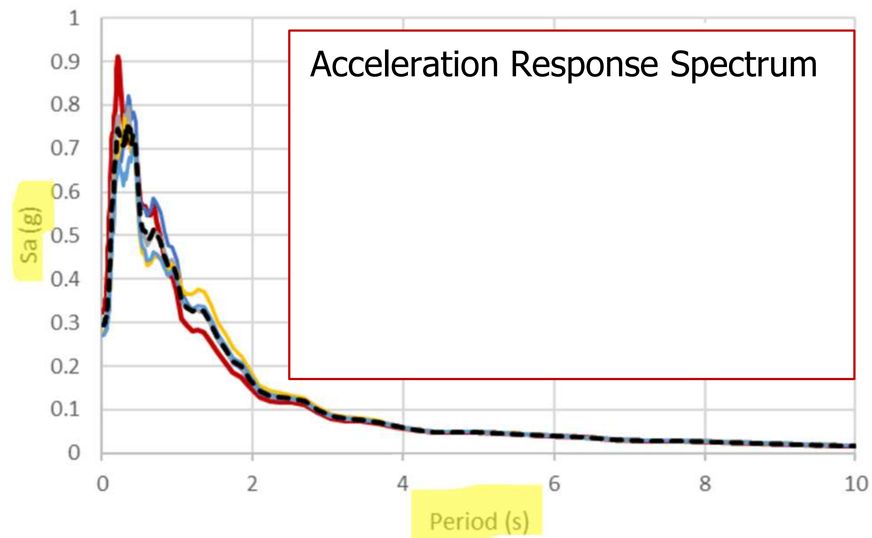
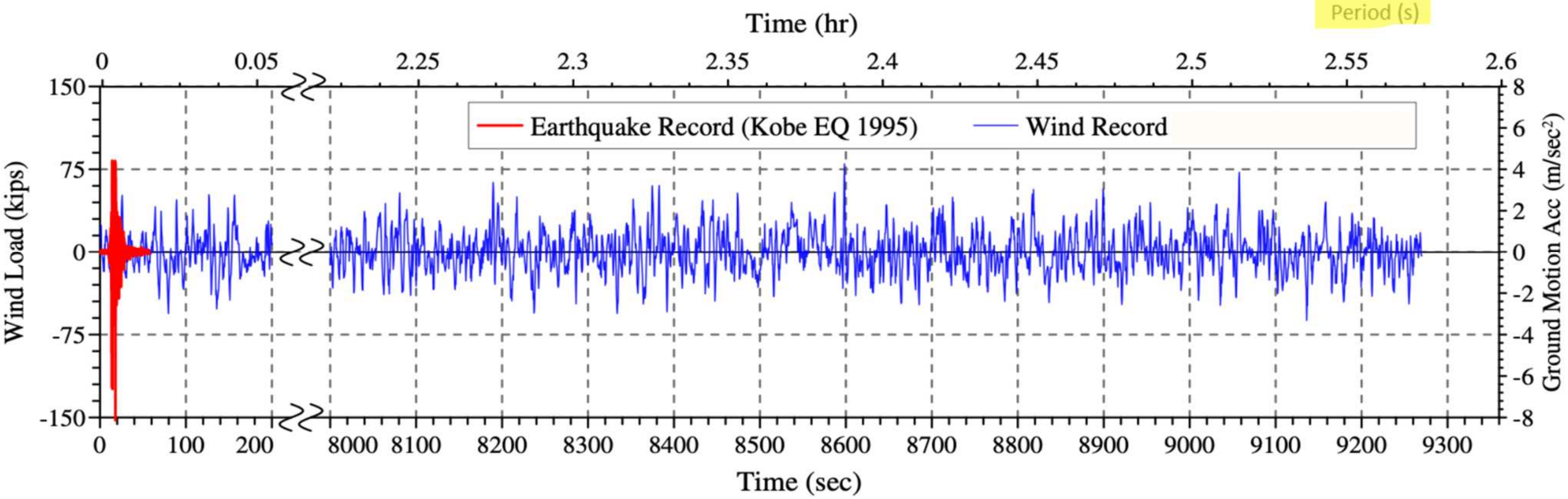
- For prescriptive design, time history analysis is rarely used
  - Wind loads are applied as static loads
  - Earthquake demands are determined using "modal response spectrum analysis"
- PBSD and PBWD rely on time history analysis





2. PBD In A Nutshell

PBD in a Nutshell

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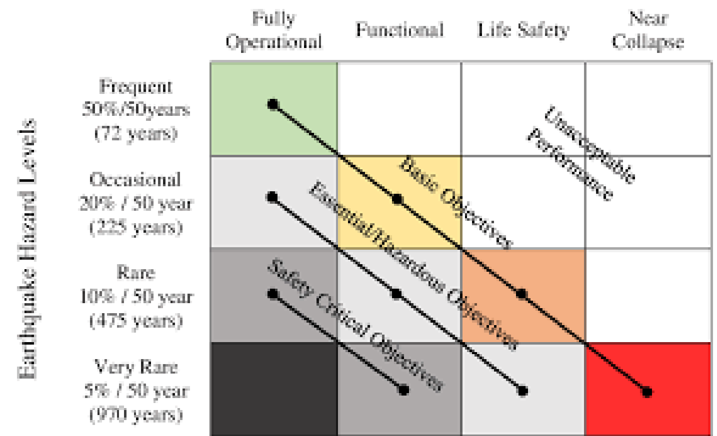
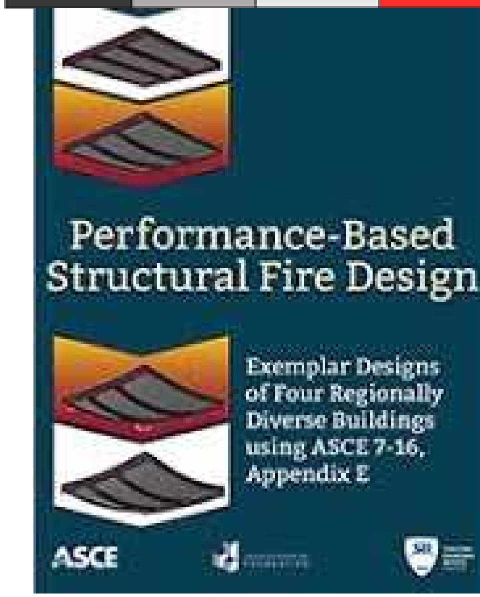
A summary of PBD:

PBD is a methodology through which a building system is explicitly modeled, analyzed, and evaluated to meet certain performance requirements as specified by owners, end users, and other stake holders.

Advantages:

- Explicitly defines and measures performance of tall buildings for seismic and wind effects
- Results in consistency between seismic and wind design and negate negative effects of wind design on seismic performance
- Results in a cost-effective design for both wind and seismic
- Enhances reliability of buildings
- Accommodates architectural features
- Helps to advance wind design to get to resilience-based design





PBD in a Nutshell

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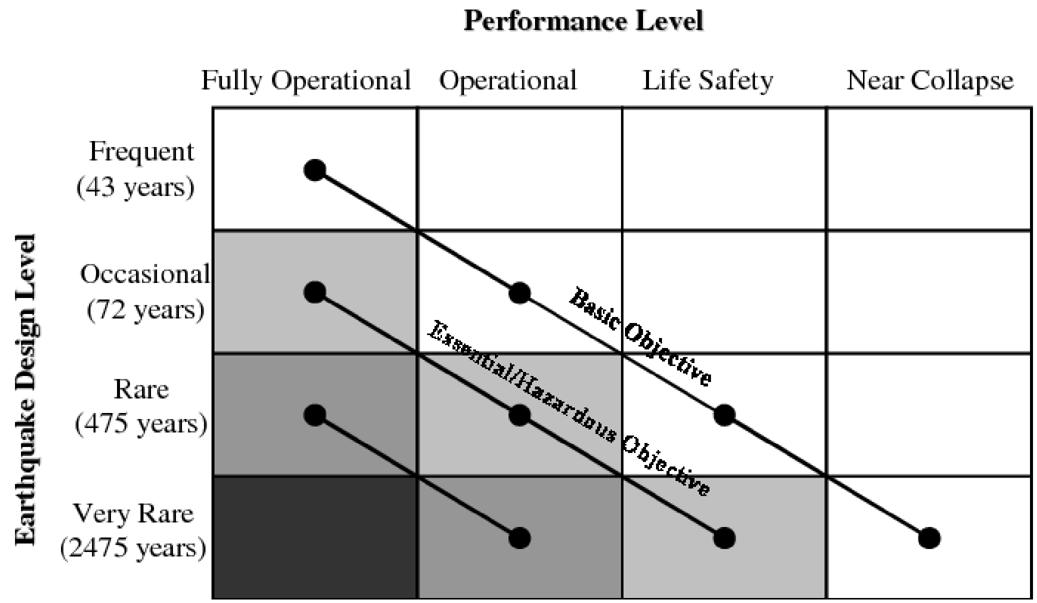
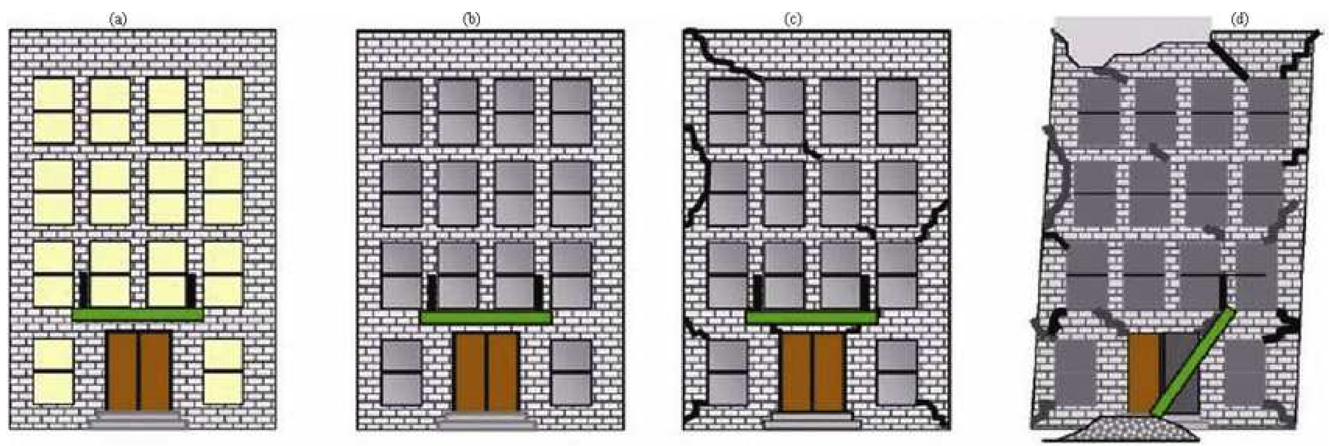
- Performance Based Design relies on different expected performance levels for different hazards.
- For example, the rare earthquake can be described as a 10% probability of exceedance in 50 years.
- The “Rare” seismic event is the one associated with prescriptive seismic design (ASCE 7)





PBD Methodology

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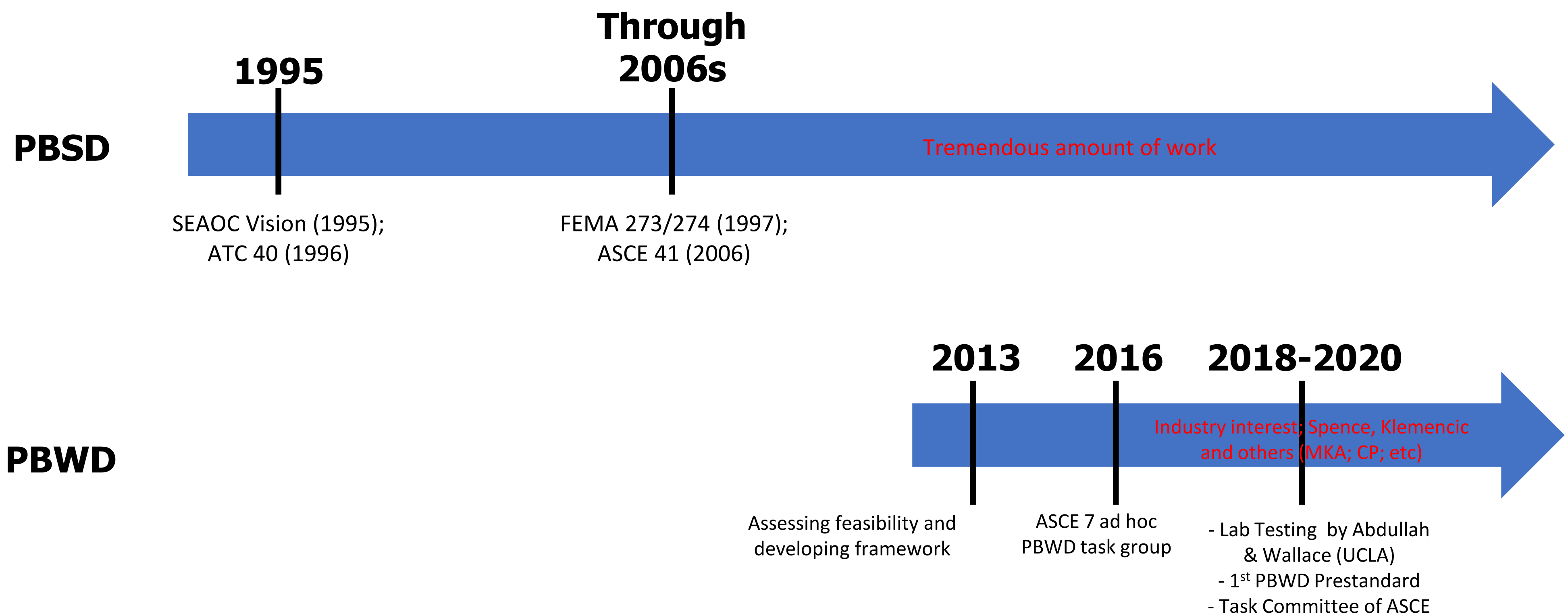
- PBD definition in general
- PBSD: Developed through extensive research over the last two decades (used in many projects)
- PBWD: Just recently started (used in very few projects). **PBWD started late and is behind**.



Evolution of Design Approaches

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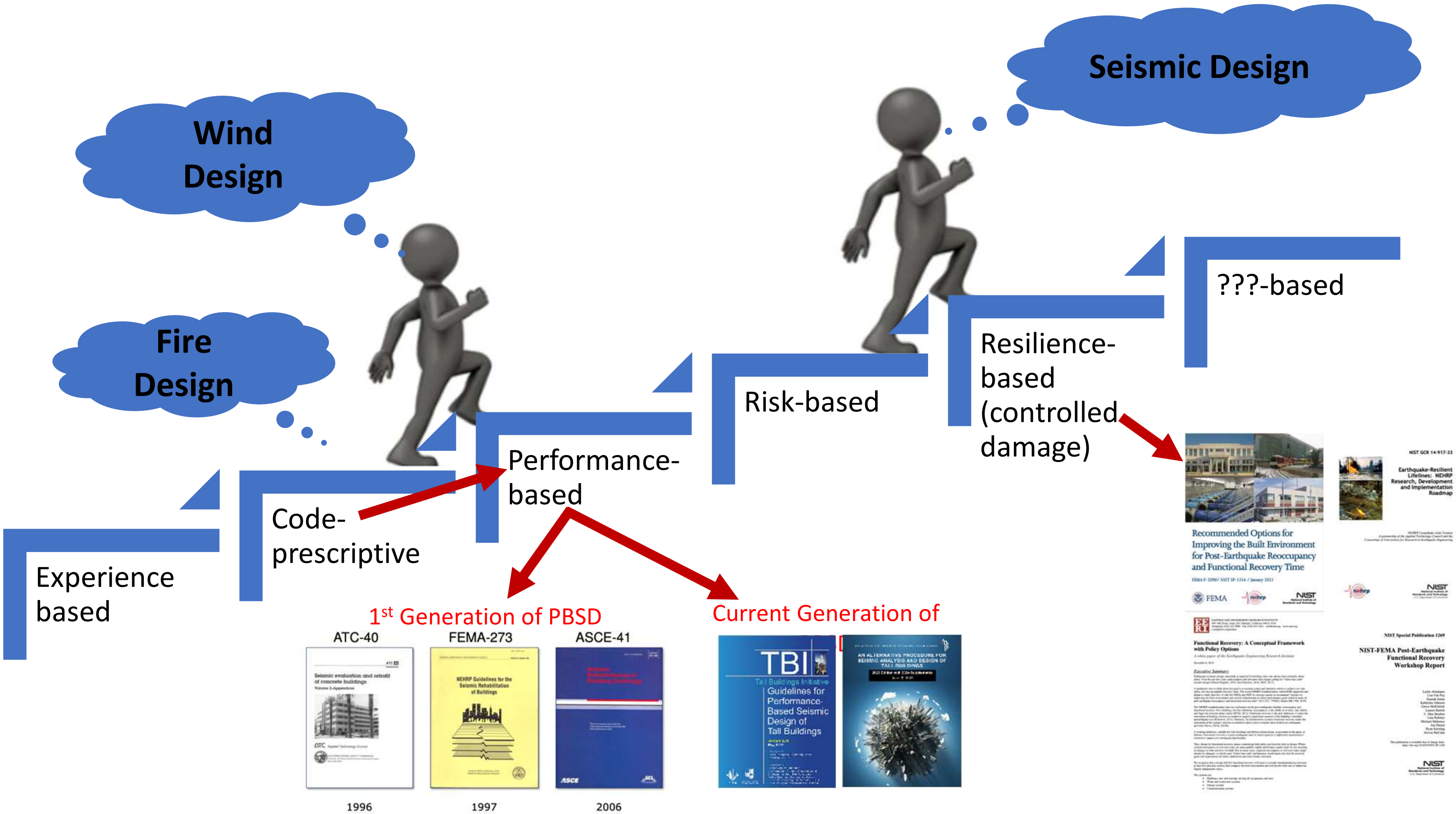

PBD Vocabulary

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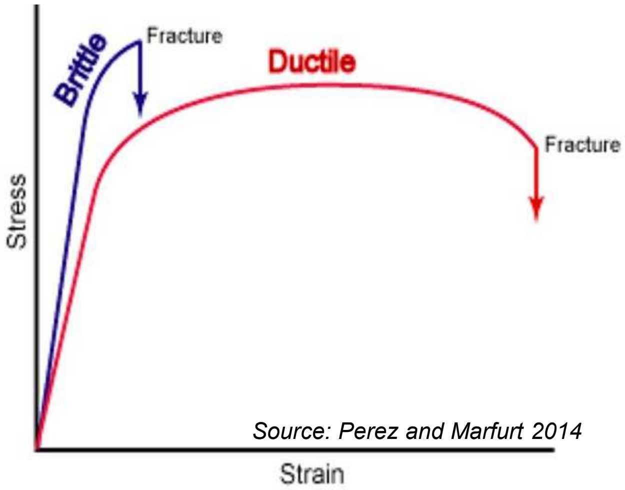
Deformation-controlled

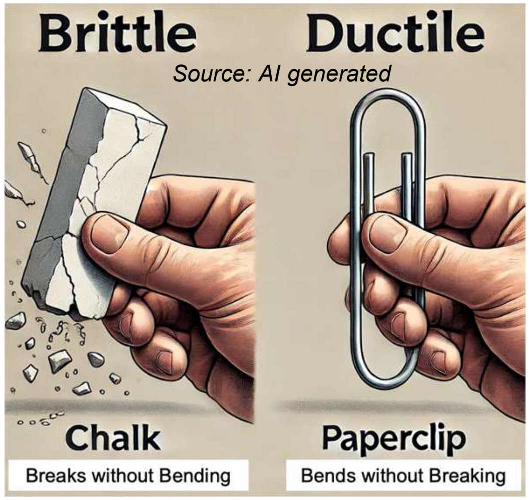
- An action allowed to exceed the expected yield deformation of element
- Ductile behavior through proper detailing



Source: Perez and Marfurt 2014

Force-controlled

- An action not allowed to exceed design strength of element.
- Sufficient strength to avoid brittle behavior



Additional Terminology

- DCR: Demand to capacity ratio
- AHJ: Authority having jurisdiction
- MWFRS: Main wind force resisting system
- MRI: Mean recurrence interval
- MP: Modeling parameter
- AC: Acceptance criteria

PBD Vocabulary

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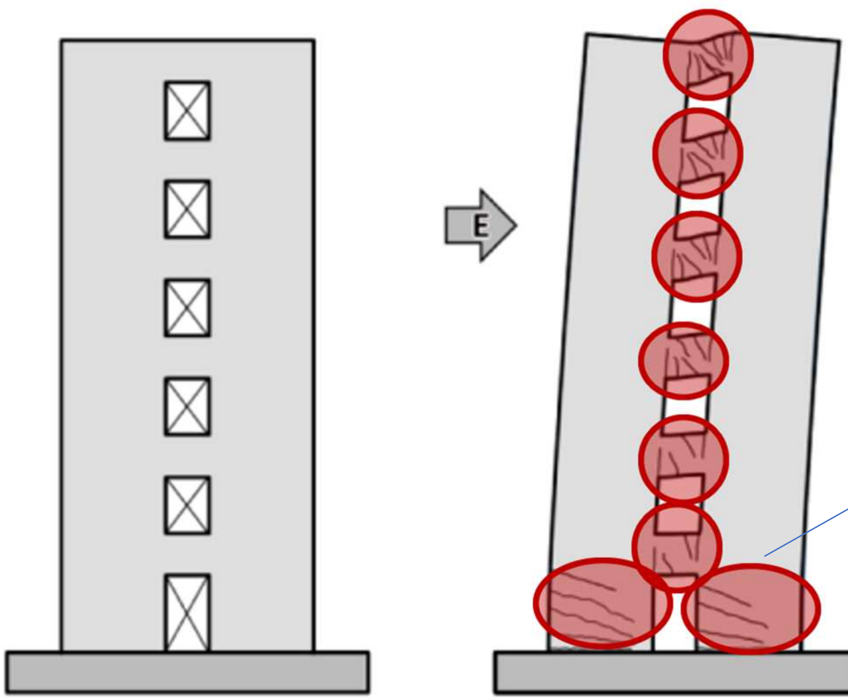
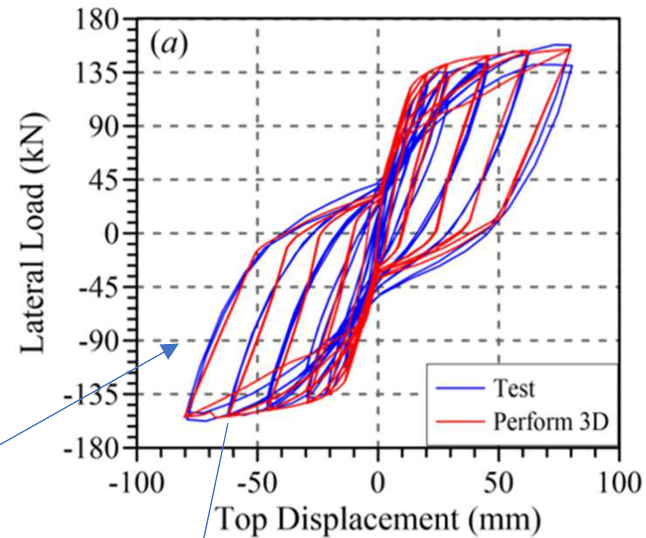
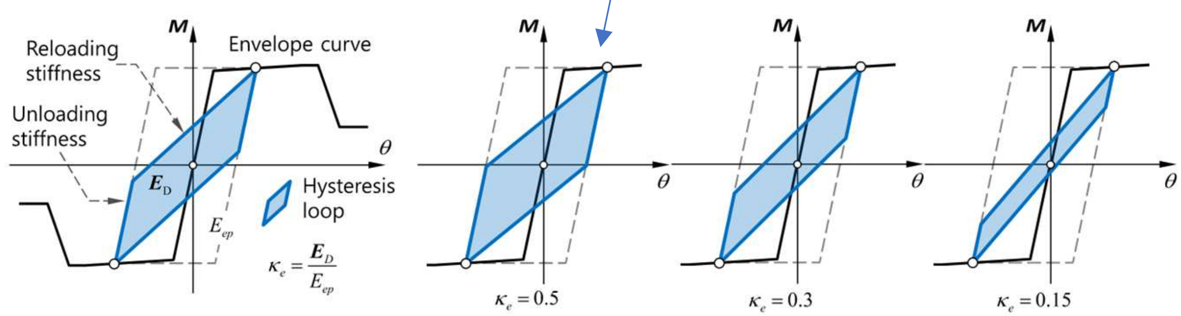
- Hysteretic Energy Dissipation = Area inside demand-deformation loop
- Desired in deformation-controlled elements







(a) Energy dissipation ratio κ_e

(b) Hysteresis shapes varying with energy dissipation ratios

PBD Vocabulary

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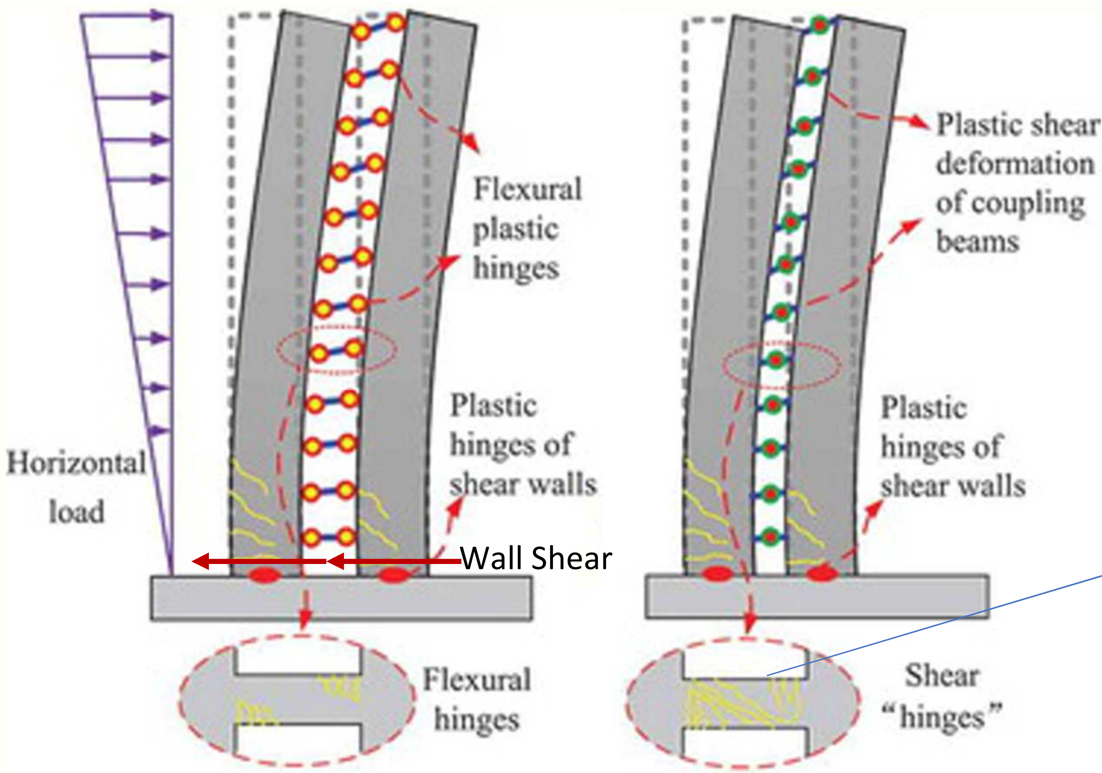
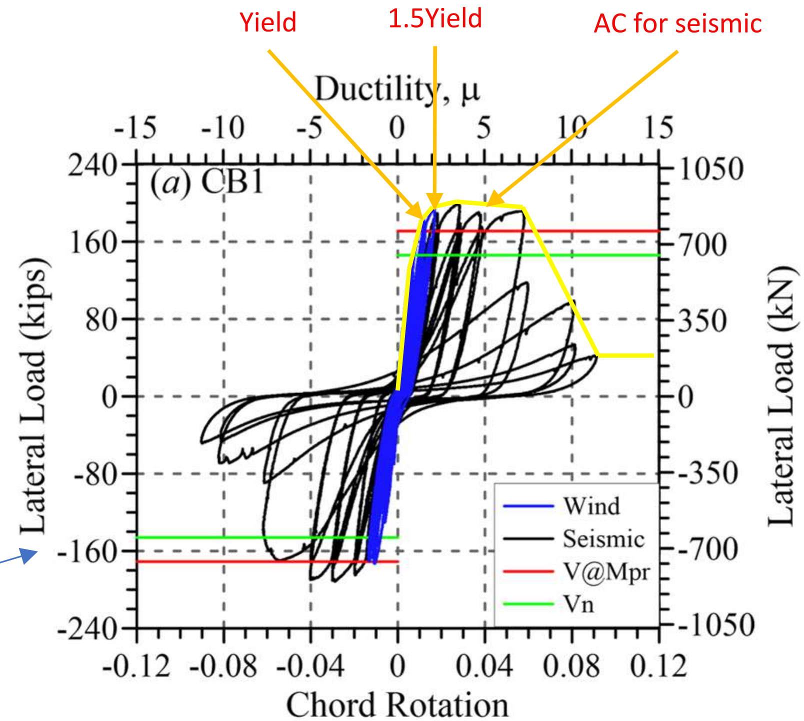
- For deformation-controlled elements, there are “Acceptance Criteria” (AC) for allowed inelastic deformations (displacement, strain, rotation).
- AC depends on the performance objective



Source: Yang Liu, Hai Chen, Zi-Xiong Guo & Hong-Song Hu (2020)



Source: Abdullah et al. (2020)

3. PBSD

Evolution of PBSD

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- The 1st PBSD building in Seattle circa 1998 (1700 7th Ave)
- Lateral system is a Special Reinforced Concrete Shear Wall (not a dual system)
- Analytical tools for nonlinear dynamic analysis of wall structures were not readily available at the time (last century)
- Peer reviewer accepted an equivalent “stick” model
    - Vertical elements at wall CG location
    - Used DRAIN 2DX
    - Compiled in a DRAIN compatible Takeda element
    - Used seven spectrum-compatible time-history pairs, axial load and variable stiffness assumptions.
- Average response used to determine:
    - Maximum wall shear
    - Wall rotations -> verify wall confinement and strain conditions
    - Roof drift

Evolution of PBSD

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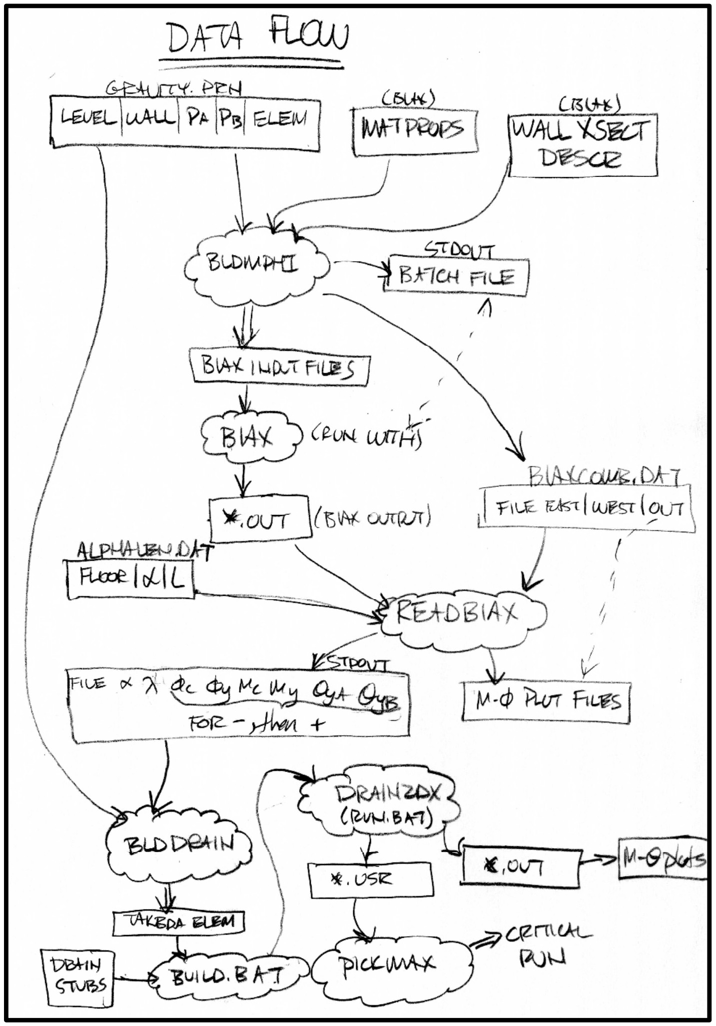

← Left Image

Custom data flow for pre and post processing

Right Image →

DRAIN-2DX model

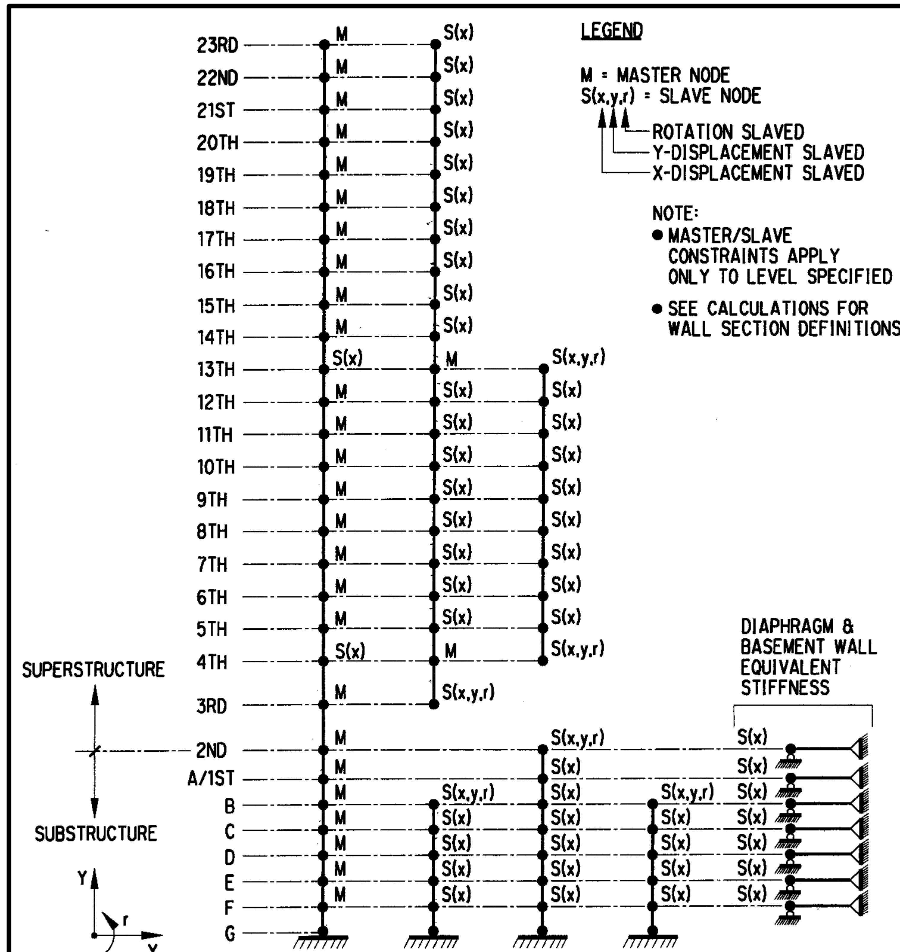

FIG. A.1 EAST - WEST NONLINEAR DYNAMIC MODEL

Evolution of PBSD – Phase 2

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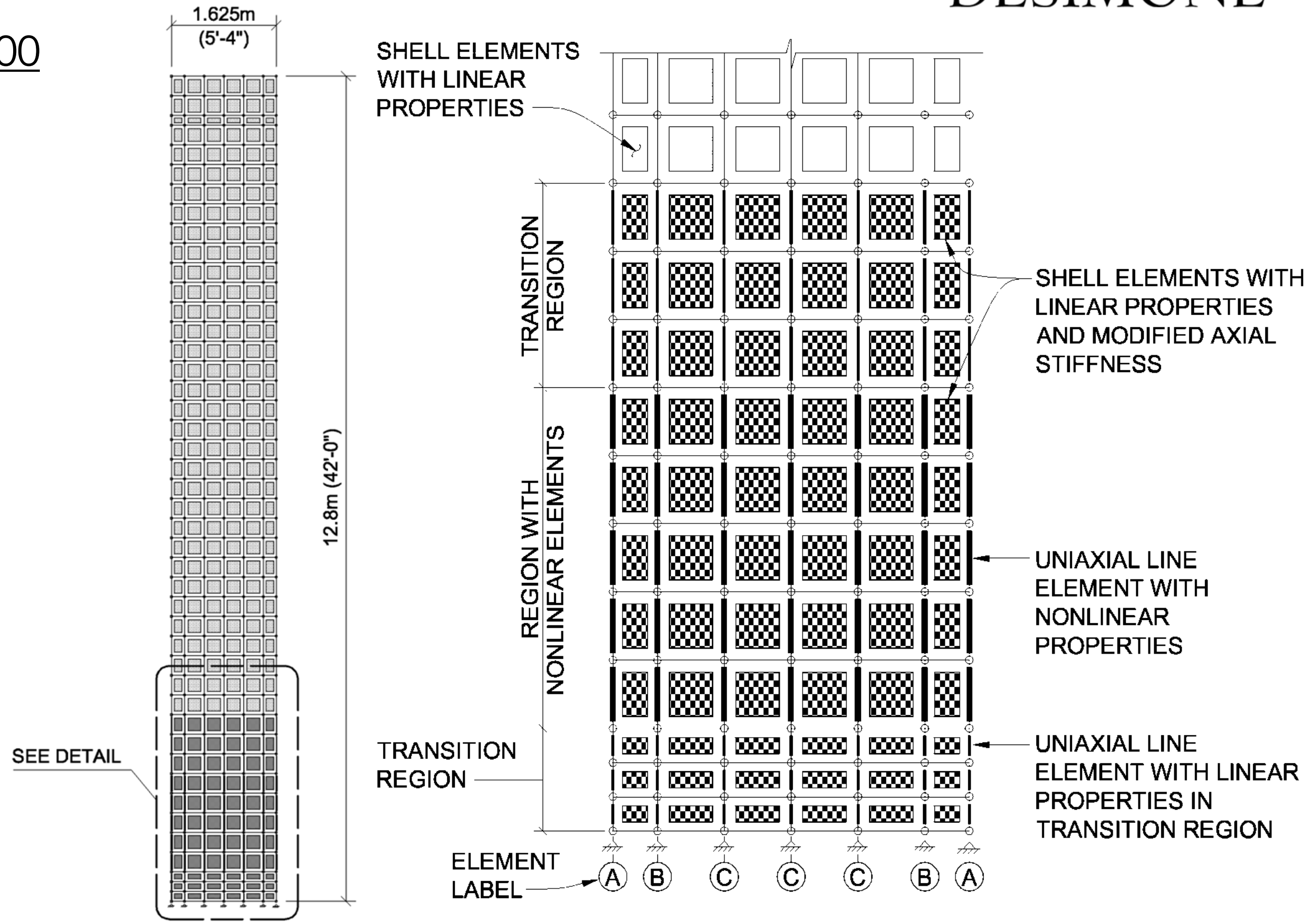
Fiber modeling in SAP2000

Static test by Adebar and Ibrahim (2002)



Evolution of PBSD – Phase 2

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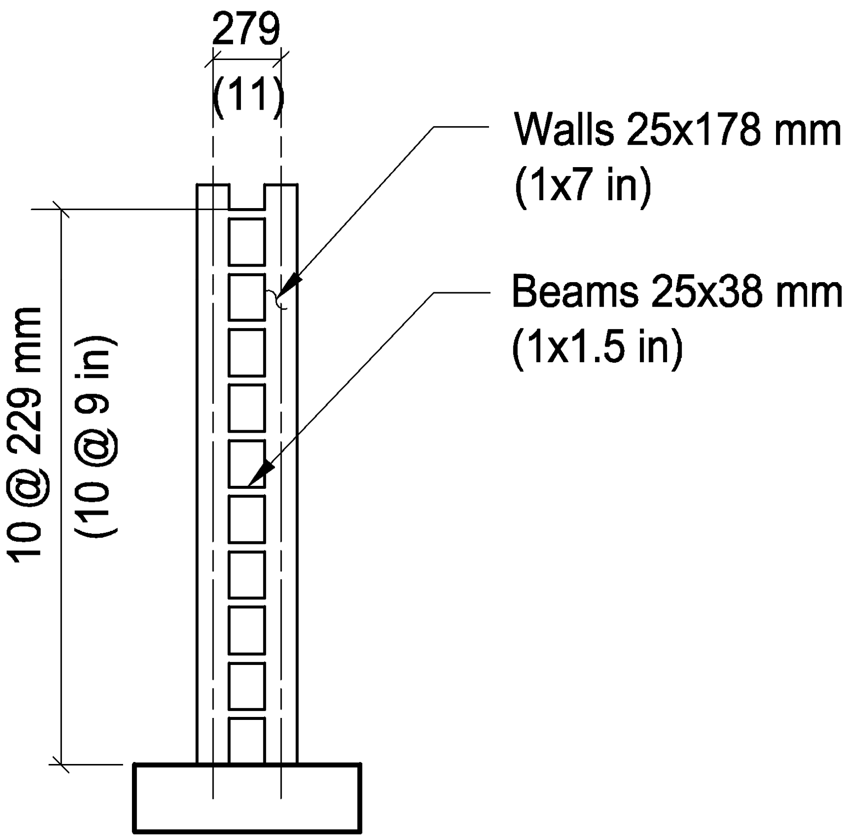
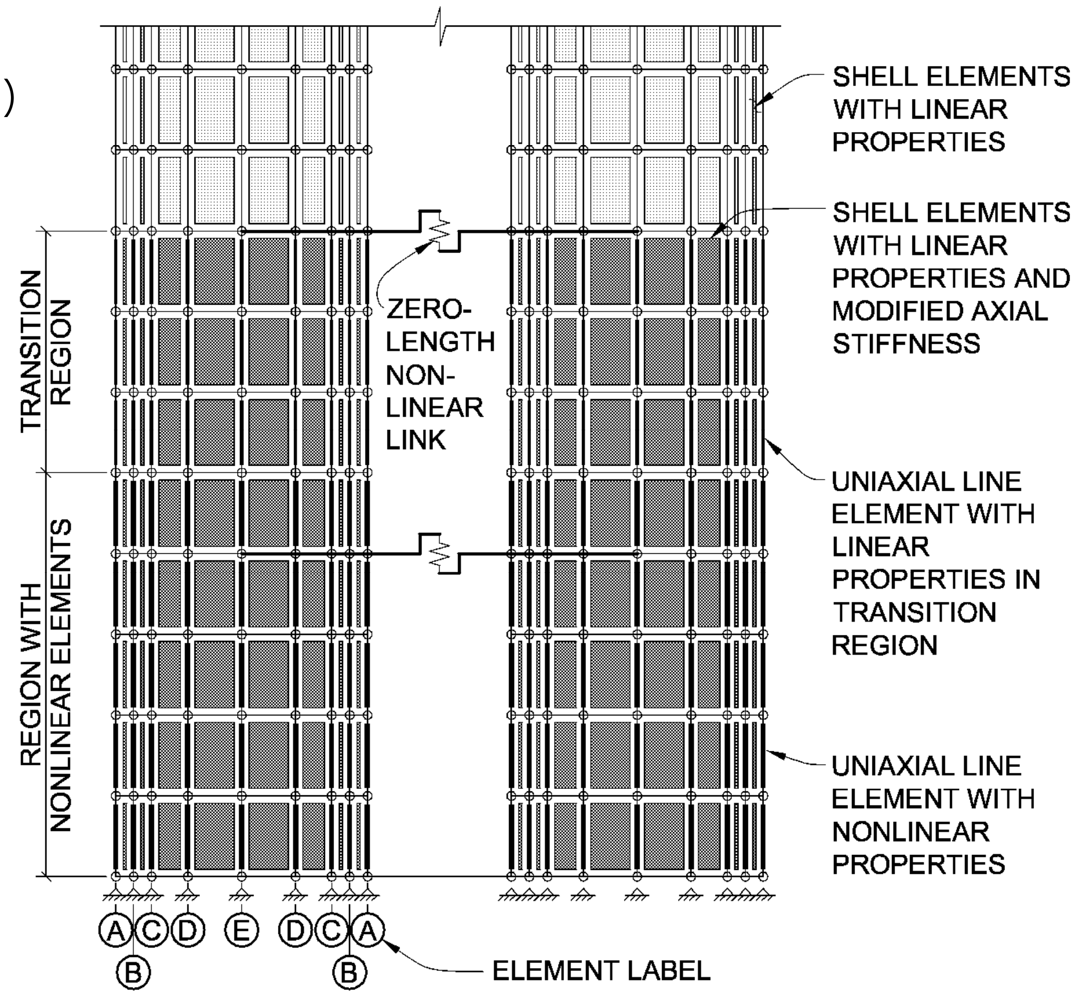
Fiber modeling in SAP200

Dynamic test by Aristizaba and Sozen (1976)





Evolution of PBSD – Phase 2

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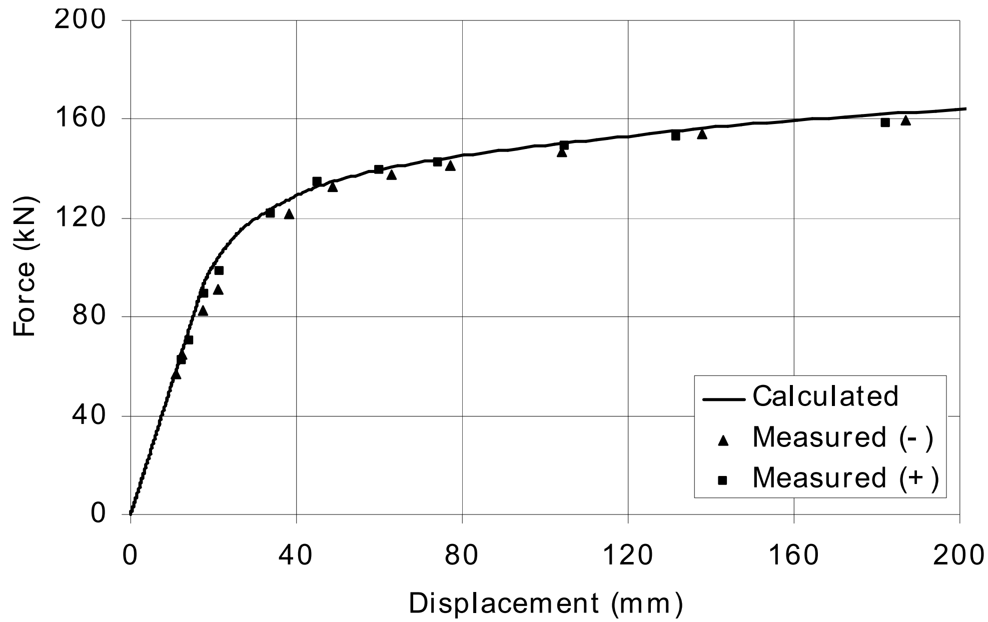
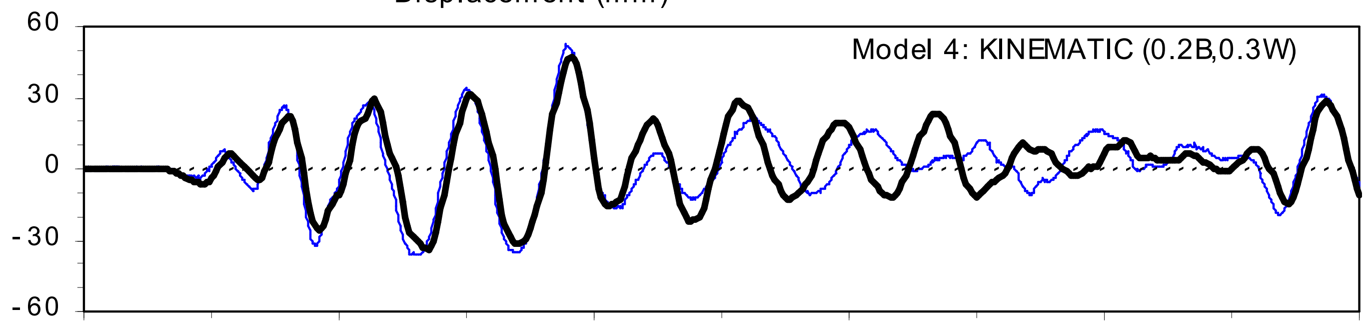
Results[1]

Adebar and Ibrahim (2002) →



Aristizaba and Sozen (1976) →



1. Lepage, A., Neuman, S. L., and Dragovich, J. J. (2006). "Practical Modeling for Nonlinear Seismic Response of RC Wall Structures," Proceedings of the 8th U.S. National Conference on Earthquake Engineering.

The PBSD Framework

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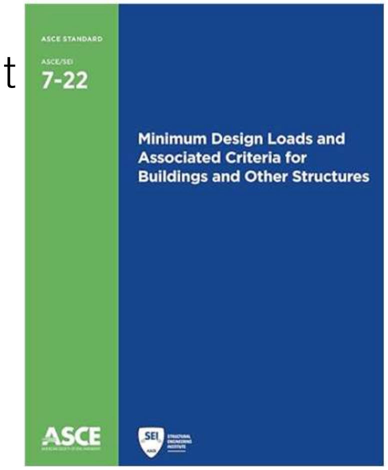
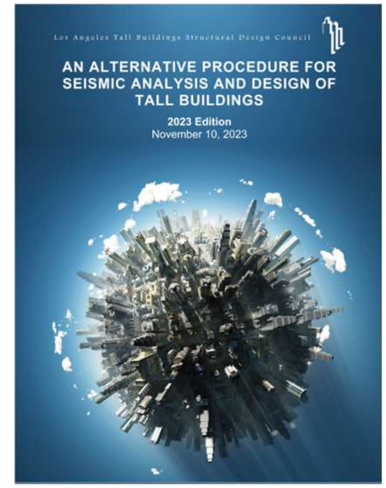
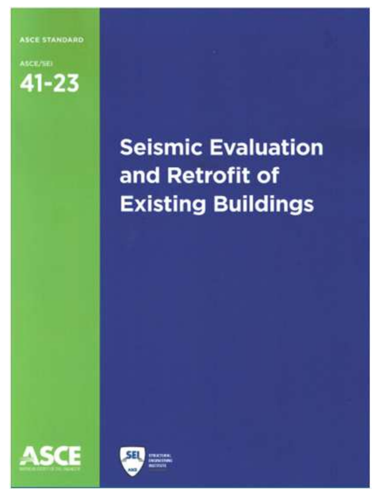
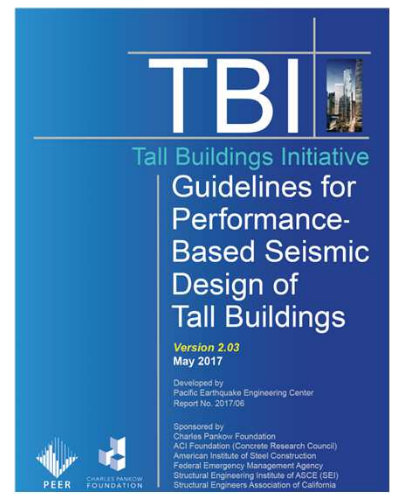
- What is presented is “West Coast USA Grown”
- ASCE 7 12.2.1.1 “Alternative Structural Systems” gives an out
- Why PBSD?
    - Overcome height limits in ASCE 7
    - Dual System not required
    - Speed of construction
- The Upfront Cost of Performance Based Design
    - Additional engineering time
    - Increased analytic computation and post-processing time
    - Peer review
- The Down Stream Benefits of Performance Based Design
    - Enhanced and predictable performance
    - Freedom in structural configuration
- What follows is Los Angeles Tall Building Structural Design Council 2023 “An Alternative Procedure for Seismic Analysis and Design of Tall Buildings”









Structual Design in a PBSD Framework

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The LATBSDC Approach

Table 1. Summary of Basic Requirements

Design / Evaluation Step	Ground Motion Intensity[1]	Type of Analysis	Type of Mathematical Model	Accidental Torsion Considered?	Material Reduction Factors (ϕ)	Material Strength
1	Nonlinear Behavior Defined / Capacity Design					
2	50/30	LDP[2] or NDP[3]	3D[4]	Evaluated	1.0	Expected properties are used throughout
3	MCE_R[5]	NDP	3D[4]	Yes, if flagged during Step 2. No, otherwise.	See Section 3.6	

Step 1: Capacity based design. Often required that structure be designed per ASCE 7 for 10/50

Step 2: Evaluate serviceable behavior (Frequent Earthquake Ground Motions). The purpose of this evaluation is to validate that the building's structural and nonstructural components retain their general functionality during and after such an event.

Step 3: Demonstrate a low probability of collapse (MCE_R).

The PBSD Framework

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Seismic analysis and design of the building shall be performed in three steps with the intent to provide a building with the following characteristics:

(1) The building has a well-defined inelastic behavior where nonlinear actions and members are clearly defined, and all other members are designed to be stronger than the demand imposed by elements designed to experience nonlinear behavior (Capacity Design Approach).

(2) The building's structural and nonstructural systems and components remain serviceable when subjected to service level earthquake (SLE) defined as an event with a probability of exceedance of 50% in 30 years.

(3) The building has a low probability of collapse during an extremely rare event (on the order of 10% or less, given MCE_R shaking) and the likelihood of being repairable after such event.

The PBSD Framework

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For Reinforced Concrete structures, different effective stiffness values need to be modeled

Component	*Service-Level Earthquake (SLE) Linear Models*			*Design Earthquake (DE) Linear Models*			*MCE Nonlinear Models*		
	Axial	**Flexural**	**Shear**	**Axial**	**Flexural**	**Shear**	**Axial**	**Flexural**	**Shear**
Structural walls[1] (in-plane)	$1.0E_c^{*}A_g$ *or* $0.75\ E_cA_g^{**}$	$0.75E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.5\text{-}0.6E_cI_g$	$0.75G_cA_g$	$1.0E_cA_g$	$0.35E_cI_g$	$0.5G_cA_g$
Structural walls (out-of-plane)	--	$0.25E_cI_g$	$1.0G_cA_g$		$0.25E_cI_g$		--	$0.25E_cI_g$	$1.0G_cA_g$
Basement walls (in-plane)	$1.0E_cA_g$	$1.0E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.9E_cI_g$	$0.75G_cA_g$	$1.0E_cA_g$	$0.8E_cI_g$	$0.5G_cA_g$
Basement walls (out-of-plane)	--	$0.25E_cI_g$	$1.0G_cA_g$		$0.25E_cI_g$	$1.0G_cA_g$	--	$0.25E_cI_g$	$1.0G_cA_g$
Coupling beams with or without diagonal reinforcement	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$
Coupling beams with steel-fiber reinforcement	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$1.0G_cA_g$
Steel Coupling Beams[2]	$1.0E_sA_s$	$0.07\left(\frac{\ell}{h}\right)(EI)_{tr}$ □	$1.0G_sA_{web}$	$1.0E_sA_s$	$0.07\left(\frac{\ell}{h}\right)(EI)_{tr}$ □	$1.0G_sA_{web}$	$1.0E_sA_s$	$0.07\left(\frac{\ell}{h}\right)(EI)_{tr}$ □	$1.0G_sA_{web}$
Non-PT diaphragms (in-plane)[3]	$0.5E_cA_g$	$0.5E_cI_g$	$1.0G_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$1.0G_cA_g$	$0.25E_cA_g$	$0.25E_cI_g$	$0.25G_cA_g$
PT diaphragms (in-plane)[3]	$0.8E_cA_g$	$0.8E_cI_g$	$1.0G_cA_g$	$0.8E_cA_g$	$0.8E_cI_g$	$1.0G_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$0.5G_cA_g$
Slab-Beam (out-of plane)	$1.0E_cA_g$	***	$1.0G_cA_g$	$1.0E_cA_g$	***	$1.0G_cA_g$	$1.0E_cA_g$	***	$1.0G_cA_g$
Beams	$1.0E_cA_g$	$0.5E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.3E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.3E_cI_g$	$1.0G_cA_g$
Columns	$1.0E_cA_g$	$0.7E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.7E_cI_g$	$1.0G_cA_g$	$1.0E_cA_g$	$0.7E_cI_g$	$1.0G_cA_g$
Mat (in-plane)	$0.8E_cA_g$	$0.8E_cI_g$	$1.0G_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$1.0G_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$1.0G_cA_g$
Mat[4] (out-of-plane)	--	$0.8E_cI_g$	$1.0G_cA_g$		$0.5E_cI_g$	$1.0G_cA_g$	--	$0.5E_cI_g$	$1.0G_cA_g$

The PBSD Framework (MCE)

- For MCE evaluation, elements in the structure are identified as either Force Controlled or (inelastic) Deformation controlled.

Deformation Controlled

Item		Engineering Demand Parameter	Acceptance Limit
Reinforced concrete walls (outside of primary hinge zone)	No confinement	Concrete compression strain over gage length [1]	$0.001/I_e$
		Steel tension strain over gage length [1]	$2\varepsilon_y/I_e$
	Intermediate confinement per ACI 318-19 18.10.6.5	Concrete compression strain over gage length [1]	$0.003/I_e$
		Steel tension strain over gage length [1]	$0.01/I_e$
	Full confinement per ACI 318-19 18.10.6.4 except provisions of Section 18.10.6.4(i) need not be satisfied [2]	Concrete compression strain over gage length [1]	$0.005/I_e$ ($0.01/I_e$ [3])
		Steel tension strain over gage length[1]	$0.01/I_e$ ($0.05/I_e$ [3])
Reinforced concrete walls (primary hinge zone)	Full confinement of the entire cross section per ACI 318-19 18.10.6.4 [2]	Concrete compression strain over gage length [1]	$0.005/I_e$ ($0.01/I_e$ [3])
		Steel tension strain over gage length [1]	$0.01/I_e$ ($0.05/I_e$ [3])
Coupling beams	Conventionally-reinforced [4]	Total chord rotation	$0.04/I_e$
	Diagonally-reinforced [4]	Total chord rotation	$0.06/I_e$
	Fiber-reinforced [5]	Total chord rotation	$0.04/I_e$
	Steel-reinforced	Total chord rotation	$0.06/I_e$
Slab outrigger beams	At wall end [6]	Total rotation	$0.05/I_e$
	At column end [7], with shear reinforcement, $v_{uv}/(v_c+v_s) \le 0.7$	Total rotation	$0.05/I_e$
	At column end [7], with shear reinforcement, $v_{uv}/(v_c+v_s) > 0.7$	Total rotation	$0.03/I_e$
	At column end, without shear reinforcement	Total rotation	refer to ACI 318-19 18.14.5

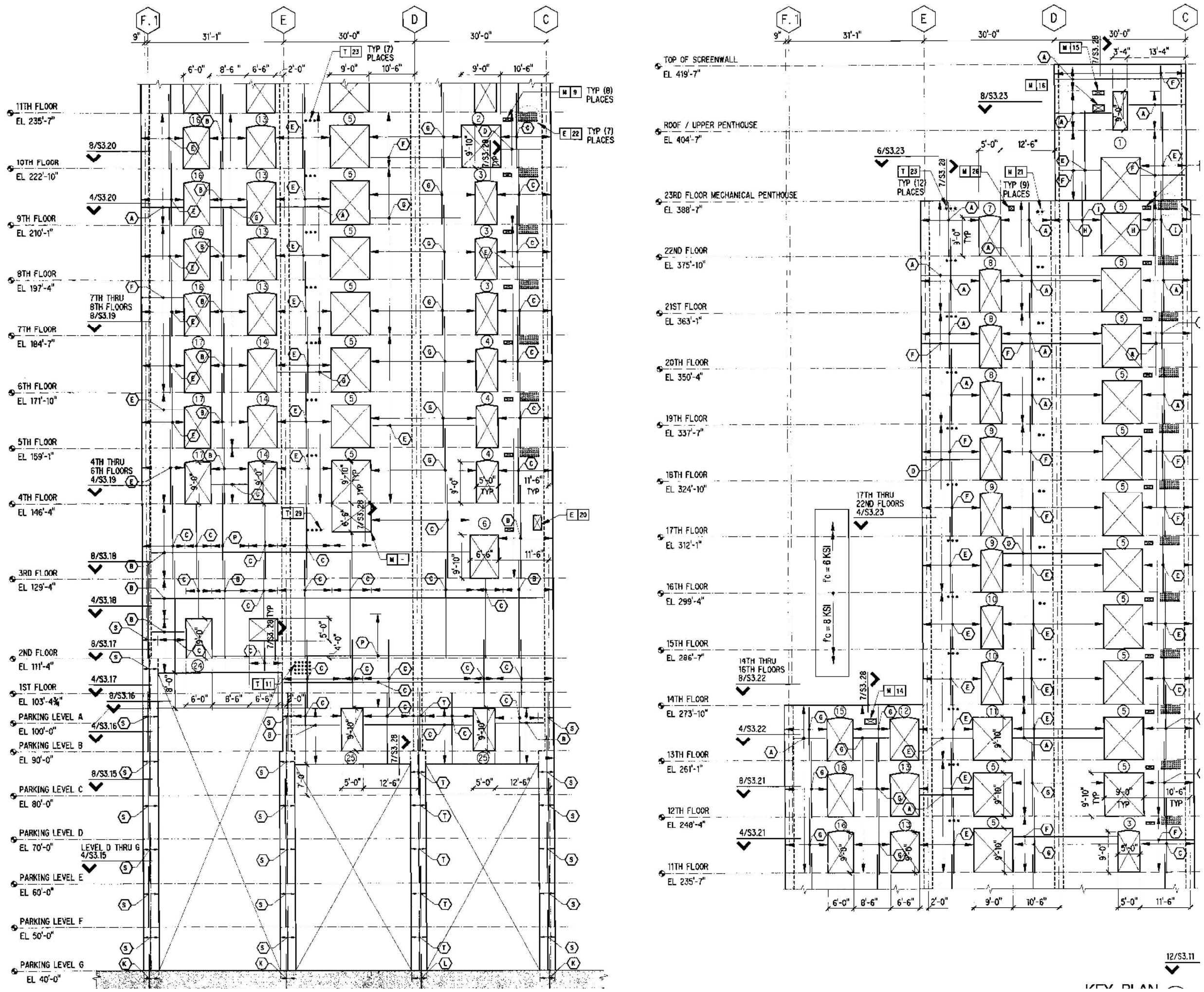
Force Controlled

	Component	Seismic Action	Category	
			Critical	Ordinary
Reinforced Concrete	Below Grade Perimeter Retaining Walls	Moment		X
		Shear		X
	Below Grade Non-Perimeter / Non-Core Walls	Shear	X	
	Core Walls Above and Below Grade and All Above Grade Walls	Shear	X	
	Diaphragms with Major Shear Transfer	Axial	X	
		Flexure	X**	
		Shear	X	
	Coupling beams without special diagonal reinforcing including steel-fiber reinforced coupling beams*	Shear	X	
	Typical (non-transfer slab) Diaphragm Forces (excludes collectors and shear transfer to vertical element)	Axial		X
		Flexure		X
		Shear		X
	All Drag (Collector) Members	Compression	X	
		Tension	X	
	Vertical Element-to-Diaphragm Connection	Bearing	X	
		Shear Transfer (Shear Friction)	X	
	Gravity Columns and Special Moment Frames (Columns, Beam-Column joints) excluding, Intentional Outrigger Columns, & Columns Supporting Discontinuous Vertical Elements)	Axial	X	
		Shear	X	
		Flexure (in P-M)	***	***
	Special Moment Frame Beams	Shear	X	
	Intentional Outrigger Columns & Columns Supporting Discontinuous Vertical Elements****	Axial	X	
		Shear	X	
		Flexure (in P-M)		X
	Transfer Girders****	Flexure	X	
		Shear	X	
	Strut and Tie in strut and tie formulation	Compression	X	
		Tension		X

The PBSD Framework

DESIMONE

- MCE evaluations are typically evaluated for the mean response of 11 ground motion pairs.
- In addition to force and deformation-controlled element evaluation, there are global drift evaluations:
    - Transient drift (during ground motion)
    - Residual drift (at end of ground motion)
- Three types of inelastic elements
    - Wall membrane sections
    - Coupling beams
    - Slab outriggers
- The nonlinear analysis for MCE is computationally intensive

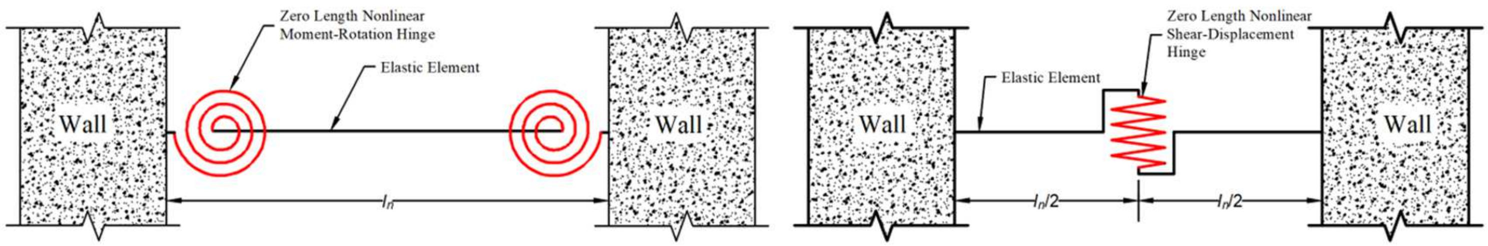


Nonlinear Element Definitions

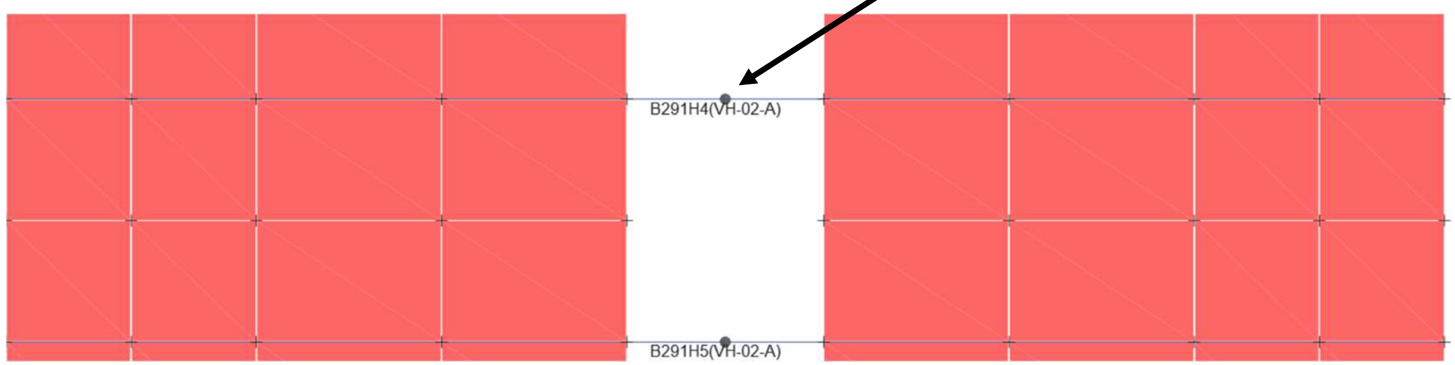
DESIMONE

Coupling Beams

- Shear-hinge model preferred due to ½ the number of nonlinear DOF's
- Hinge behavior is rigid-plastic
- Total chord rotation is used as the Engineering Demand Parameter (EDP) = plastic hinge rotation + elastic element deformation



(a) Moment-hinge model. *(b) Shear-hinge model.*

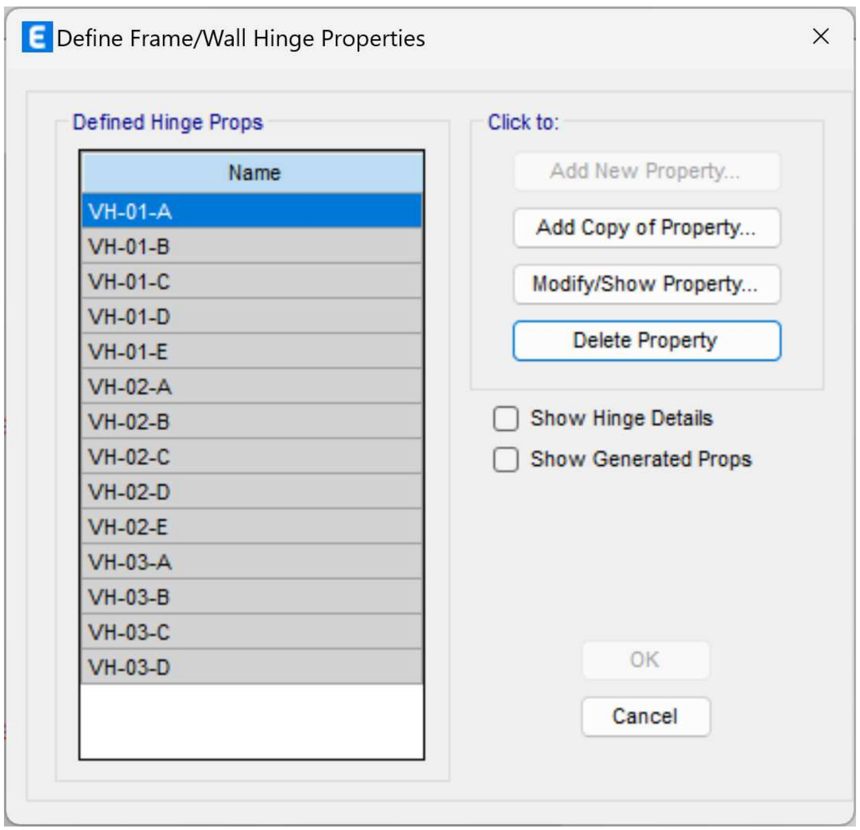


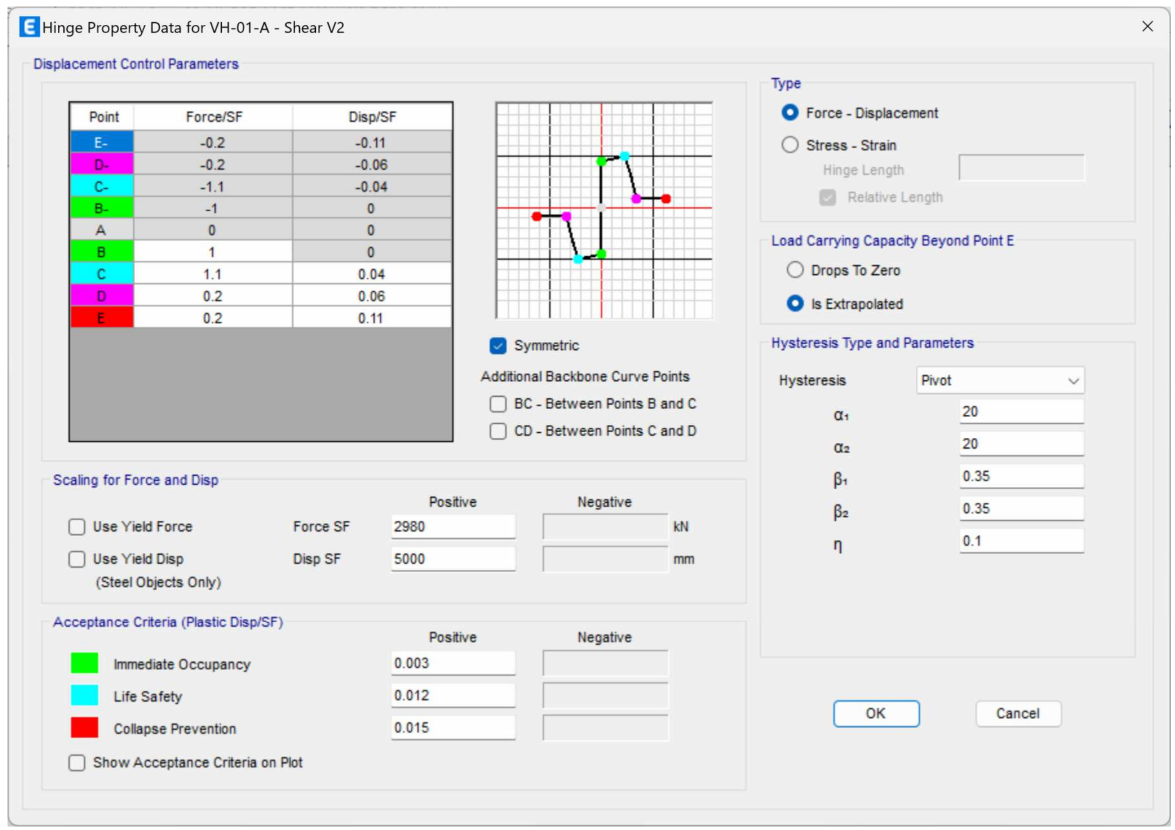
Nonlinear Element Definitions

DESIMONE

<u>Coupling Beams</u>

- ETABS example shown below
- Parameters based on calibration with experimental data



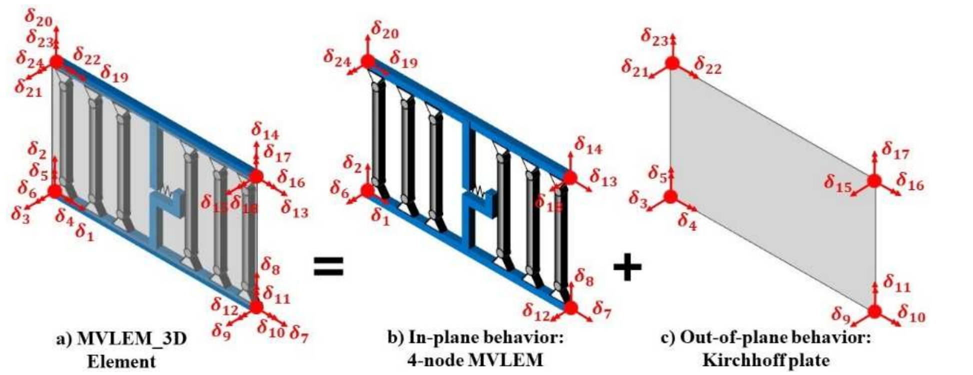


Nonlinear Element Definitions

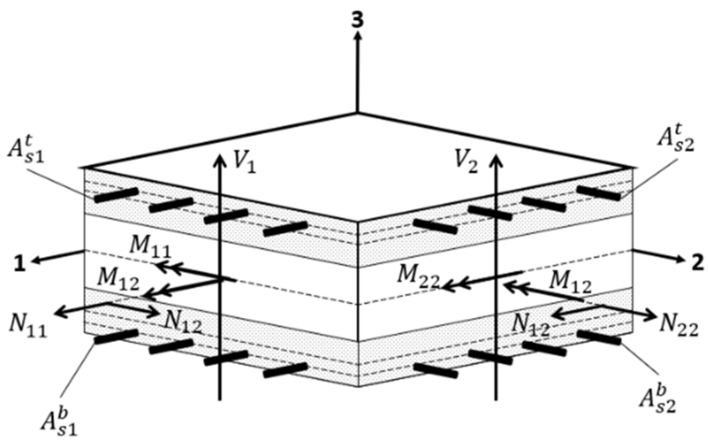
DESIMONE

<u>Wall Sections</u>

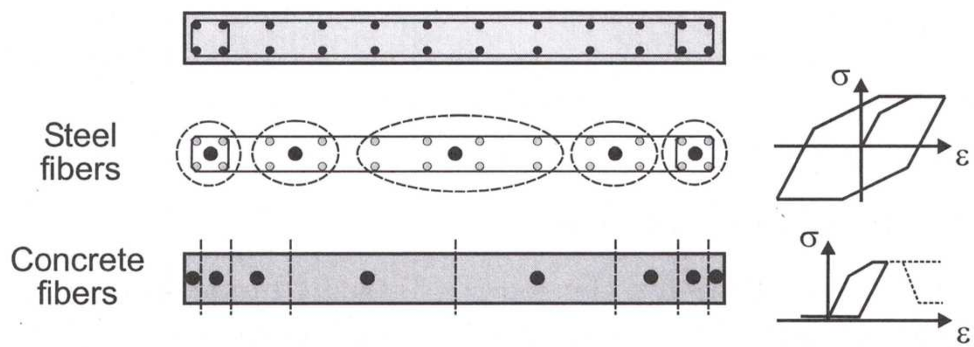
- Modeling options for Perform3D, OpenSees, and CSI ETABS/SAP2000
- Uniaxial material properties for concrete and steel are specified for vertical nonlinearity (expected properties)
- Elastic shear and plate bending behavior



<u>OpenSees</u>



<u>ETABS/SAP</u>



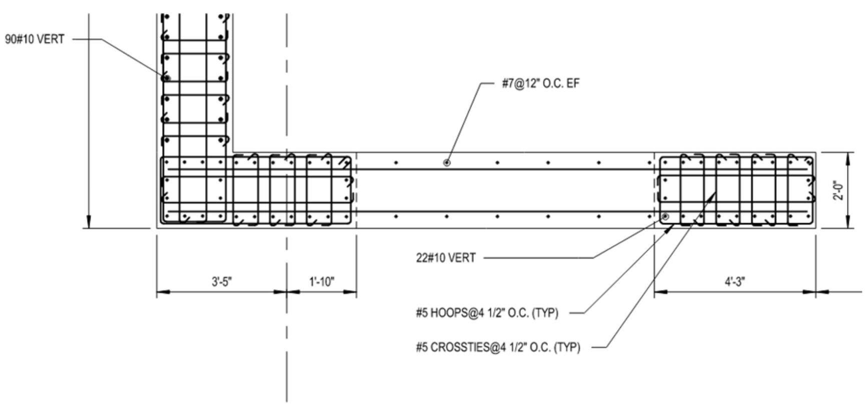
<u>Perform3D</u>

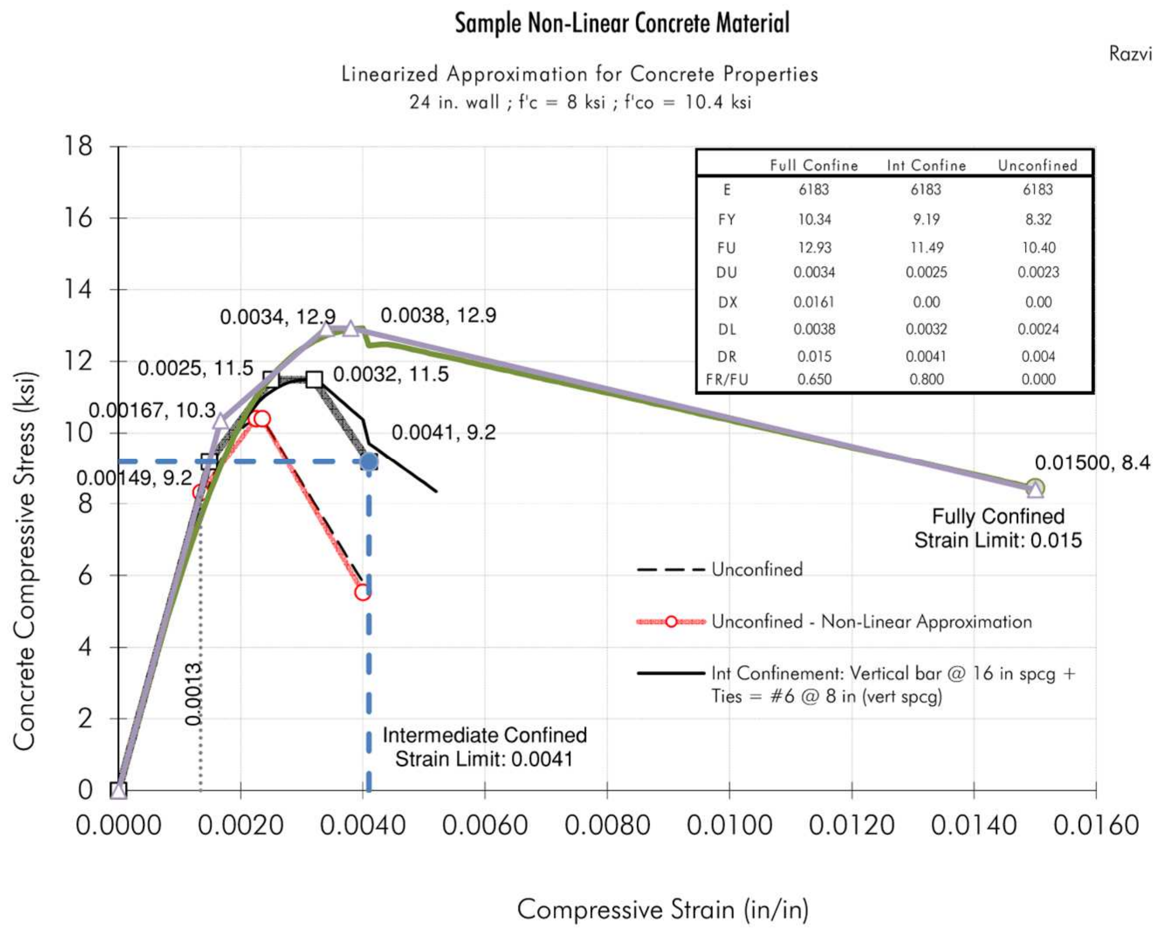
Nonlinear Element Definitions

DESIMONE

<u>Wall Sections</u>

- Concrete material uniaxial properties depend on level of confinement per ACI 318 Chapter 18:
    - Unconfined (web)
    - Intermediate (rho > 400/f_y)
    - Full
- Razvi or similar material property model is typically used





Nonlinear Element Definitions

DESIMONE

Slab Outriggers

- Slab outriggers approximate the plate bending behavior of the floor due to lateral system horizontal deformation
- Plastic hinges are located at wall and column faces with adjusted strength to account for gravity moment pre-loading effect
- Used to account for seismic force demands induced in gravity columns, and slab hinge plastic deformations

Be Aware: D+L_{exp}

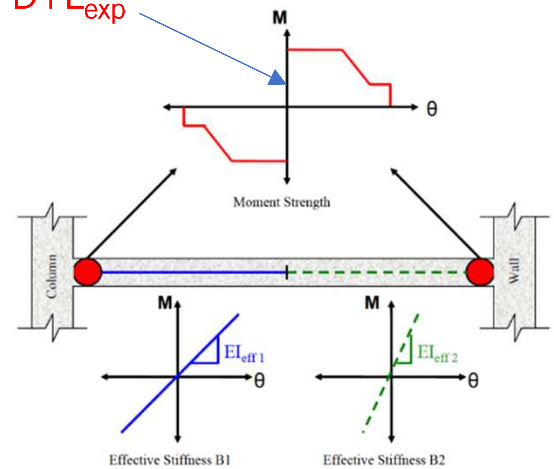


Figure C-2. Schematic of the slab model.

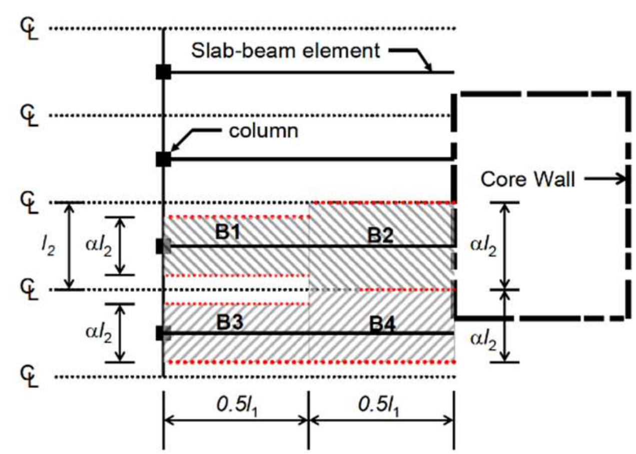
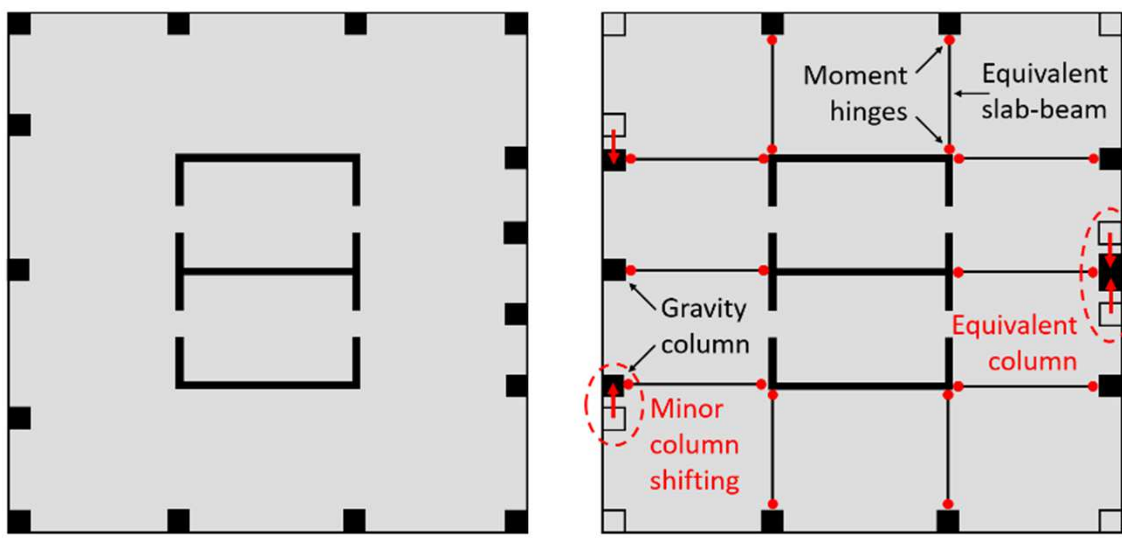


Figure C-3. Application of effective width model to core wall.



a) Floor plan b) Model

Component Model Calibration and Validation

DESIMONE

- Modeling parameters for coupling beams and walls is based on a calibration study across the following applications:
  - ETABS
  - Perform3D
  - OpenSees

Element	PBWD	PBSD
Wall	✓	✓
Diagonally Reinforced Coupling Beam	✓	✓
Conventionally Reinforced Coupling Beam	✓	✓
Steel Reinforced Coupling Beam	✓	✓
Steel Fiber Reinforced Coupling Beam		✓

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CALIBRATION OF ANALYTICAL MODELS FOR REINFORCED CONCRETE COUPLING BEAMS AND WALLS USING EXPERIMENTAL DATA TO SUPPORT PERFORMANCE-BASED DESIGN

J. Dragovich[1], S. Abdullah[2], K. Kolozvari[3] & A. Lepage[4]

[1] DeSimone Consulting Engineering, New York, USA, jeff.dragovich@de-simone.com

[2] University of Sulaimani, Kurdistan Region, Iraq

[3] California State University, Fullerton, USA

[4] The University of Kansas, Lawrence, USA

Component Model Calibration and Validation

DESIMONE

Coupling Beams

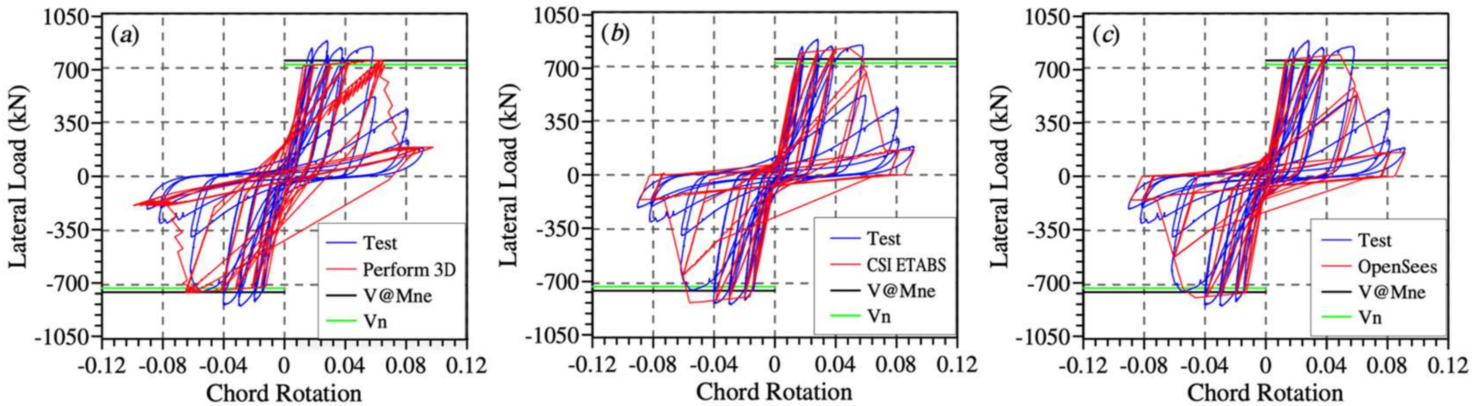


Figure 4. Load-rotation response comparison for conventionally reinforced coupling beam CB1 ($l_n/h = 2.5$) (1 kN = 0.2248 kips).

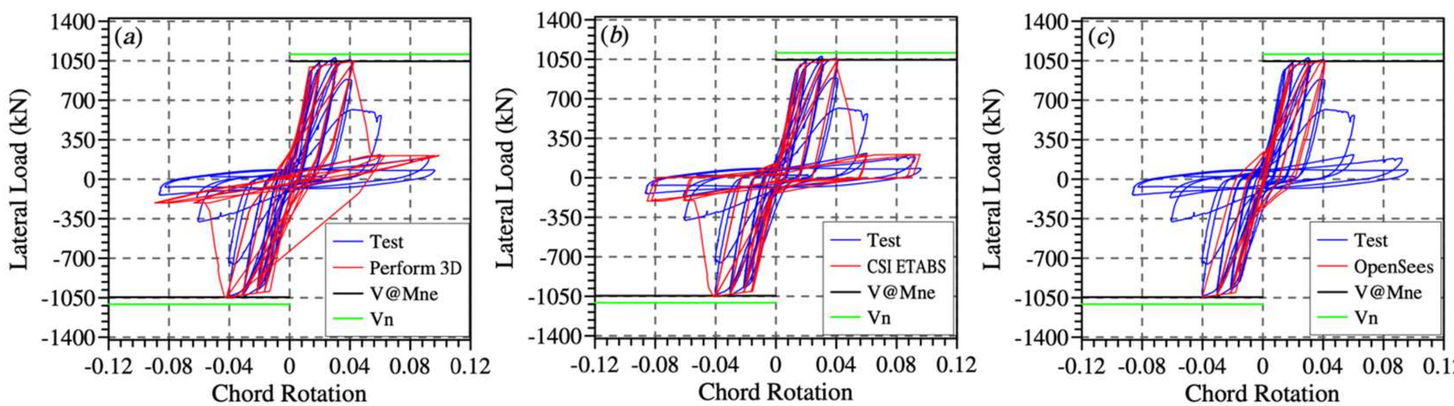
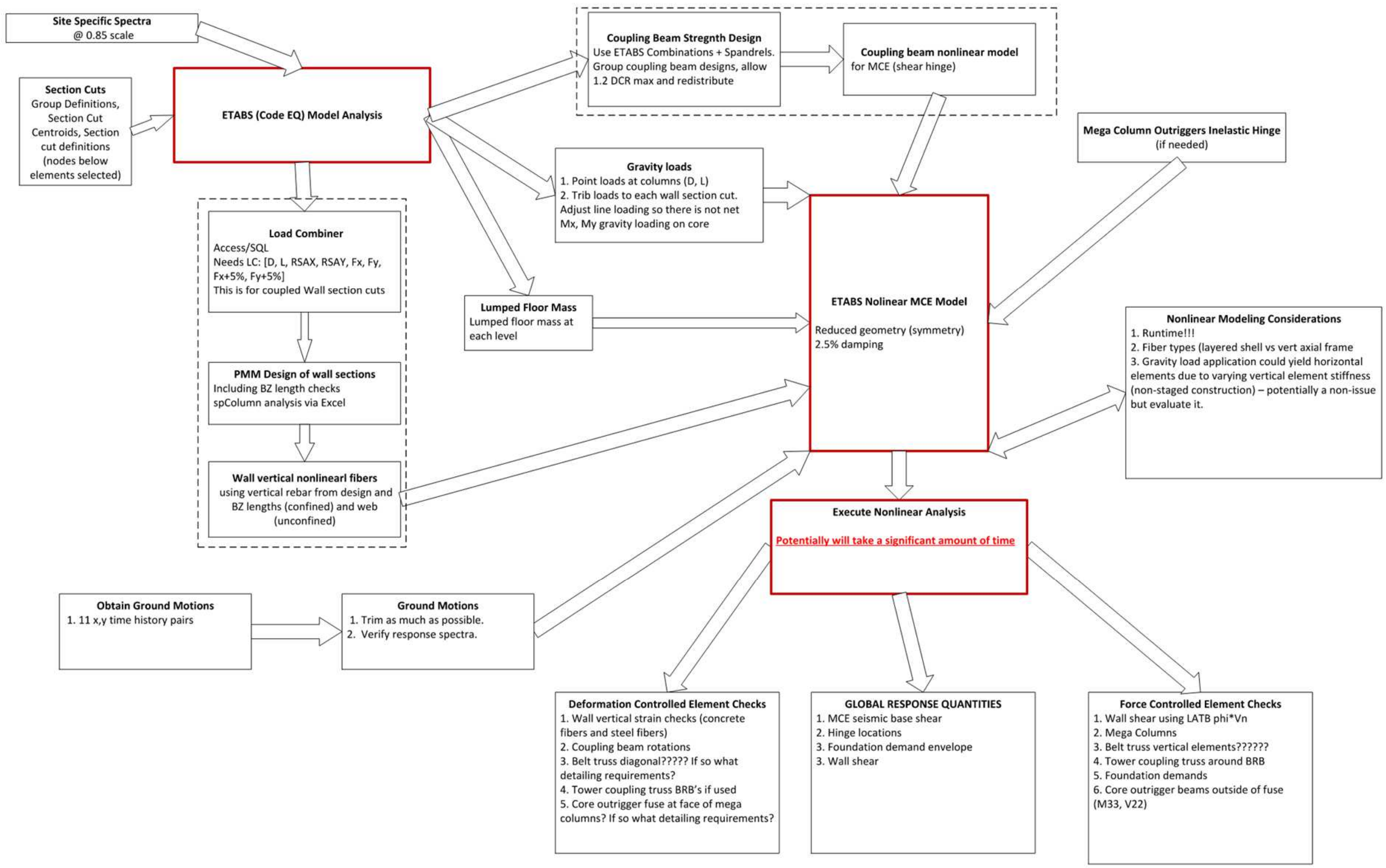


Figure 5. Load-rotation response comparison for conventionally reinforced coupling beam CB2 ($l_n/h = 3.67$) (1 kN = 0.2248 kips).

Example MCE Analysis Flowchart

DESIMONE

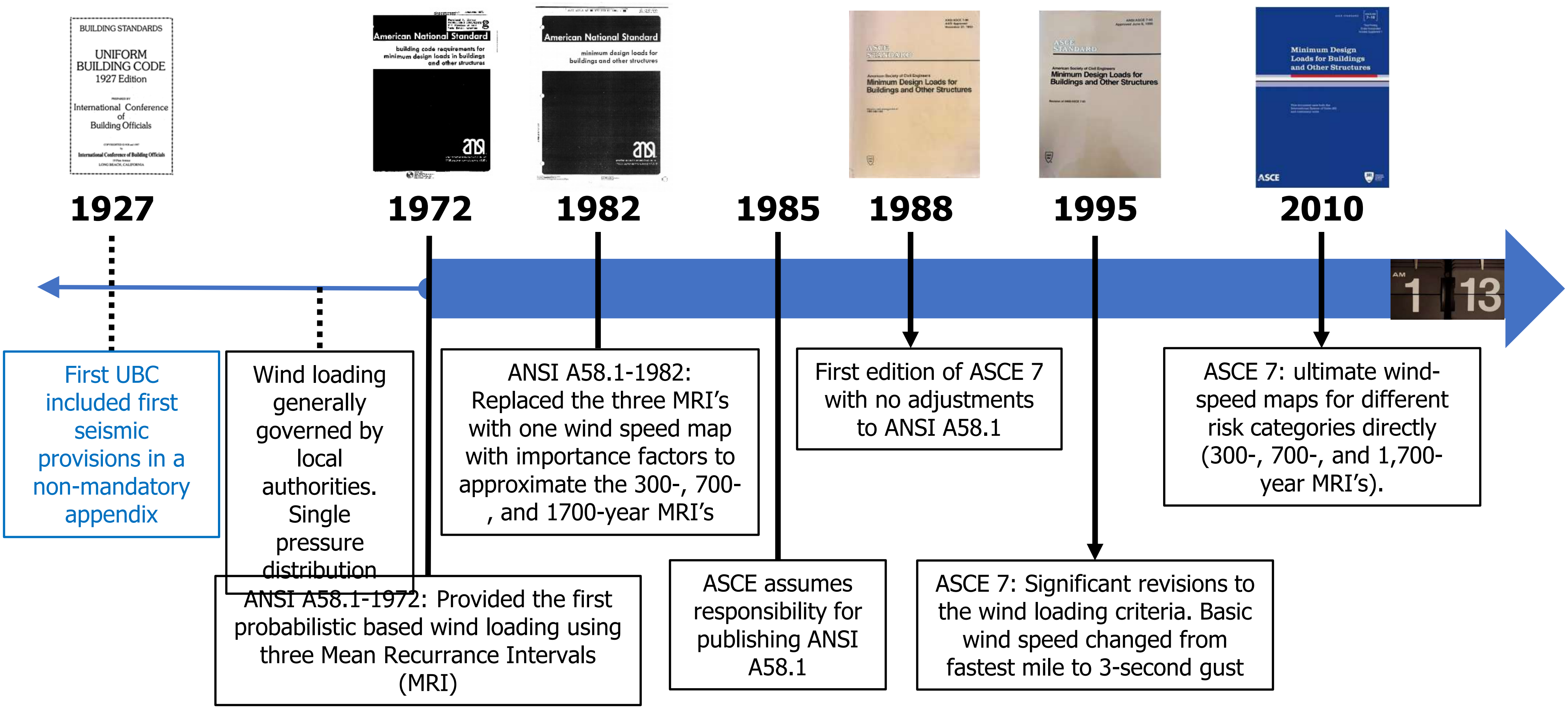


DESIMONE

4. PBWD

History of Prescriptive Wind Loading

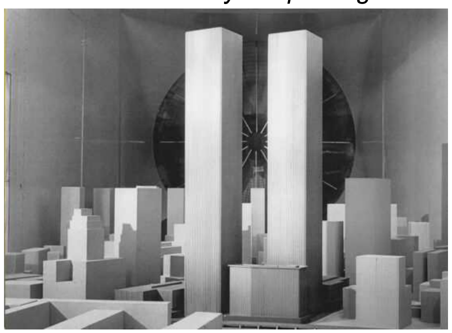
DESIMONE



History of Wind Engineering – Wind Tunnel Studies

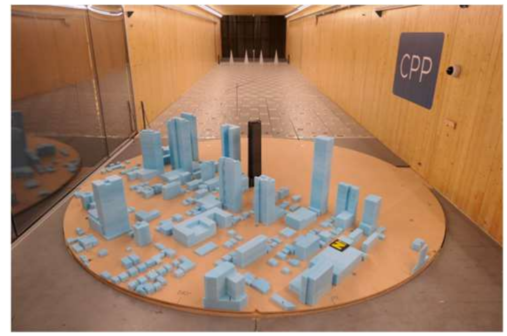
DESIMONE

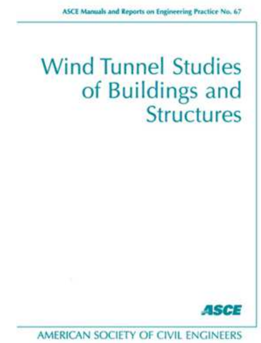
Source: skyscraper.org



Source: cppwind.com

Photograph of a Building in Miami (CPP)





1960s

Introduced (World Trade Center Towers first considered WTS)

Through 1970s

WTSs were generally limited to "special" or very tall structures

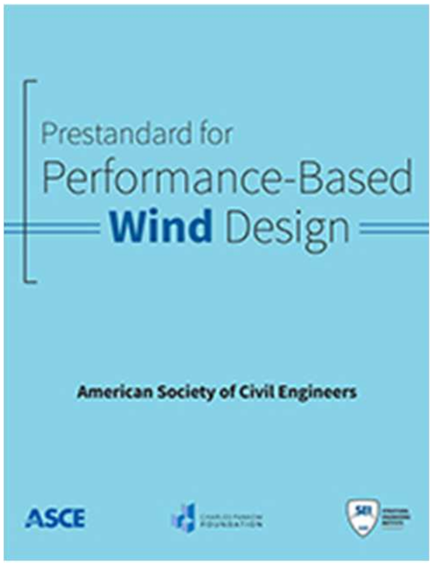
Since 1970s

Have helped designers to improve designs through more accurate knowledge of wind loads and how building responds to wind loads.

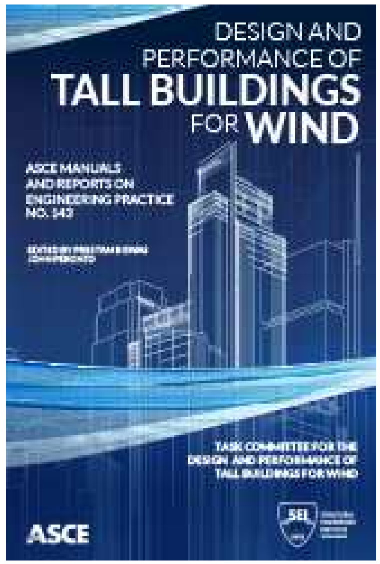
1980's

Wind Tunnel Studies of Buildings and Structures (ASCE Manuals and Reports on Engineering Practice No. 67)

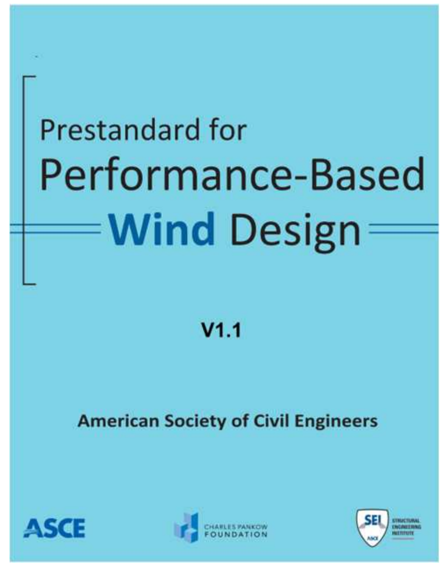
PBWD Documents



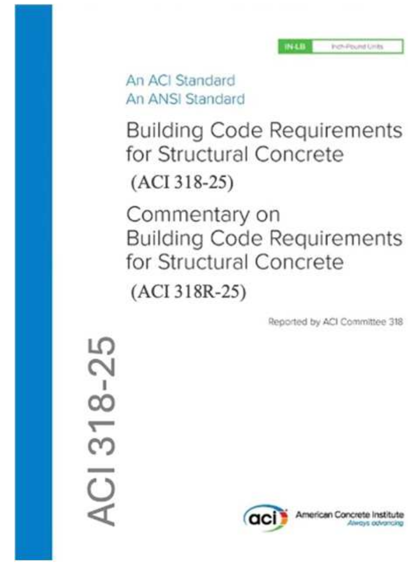
2019



2020



2023



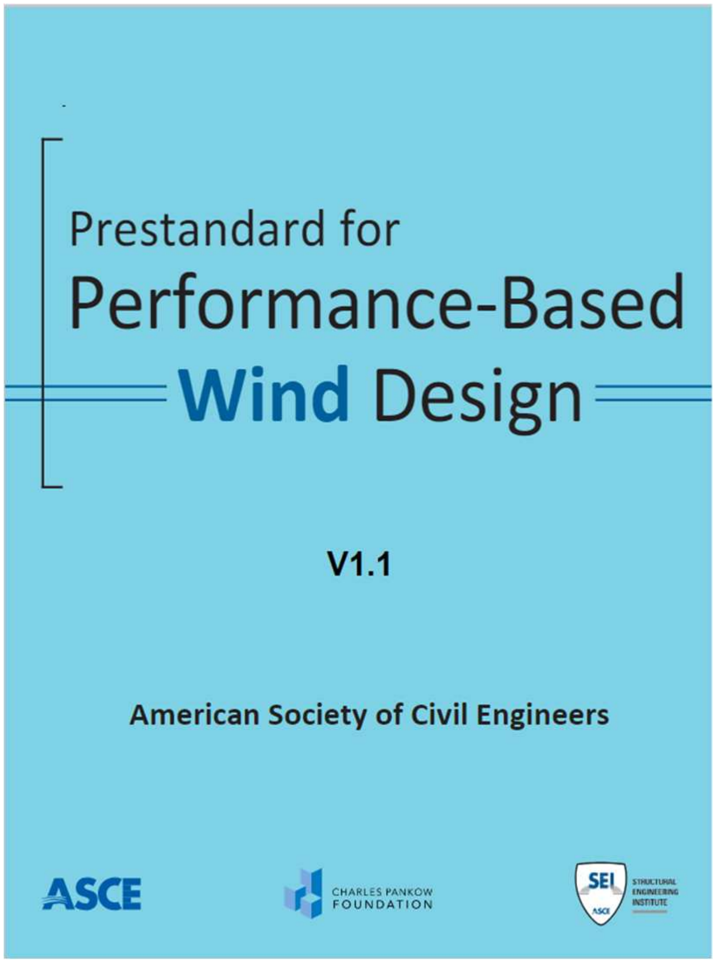
2025

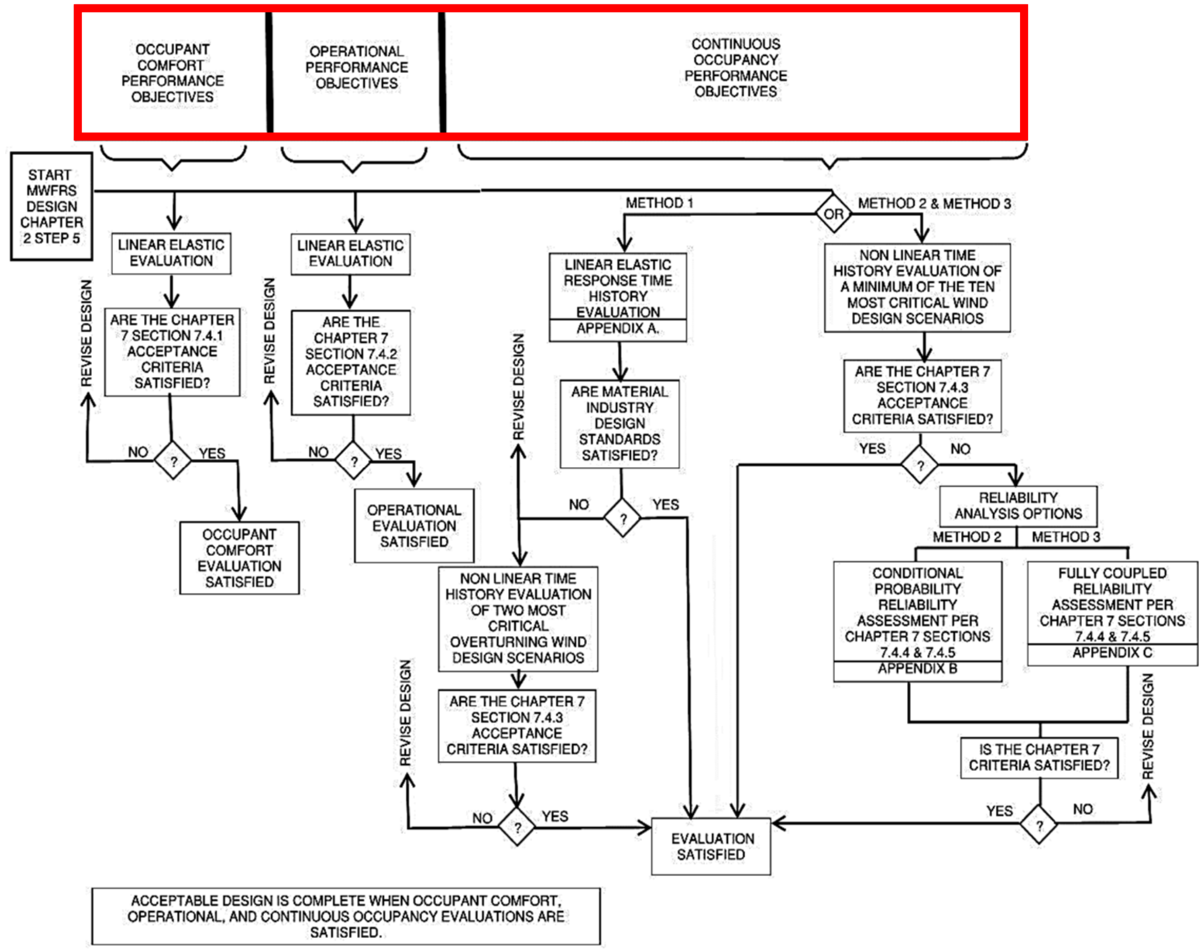
Prestandard was supported by ASCE/SEI, the Charles Pankow Foundation, ACI Foundation, AISC, MKA Foundation, and FEMA.

PBWD Procedure

DESIMONE

Performance Based Wind Design (PBWD)

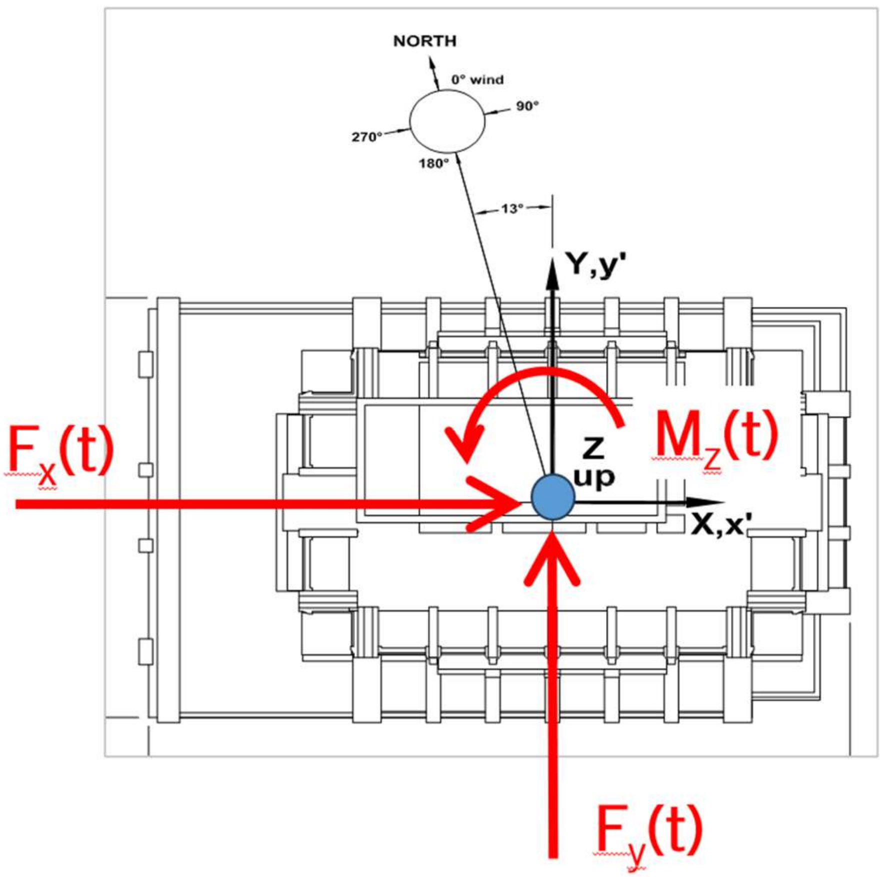




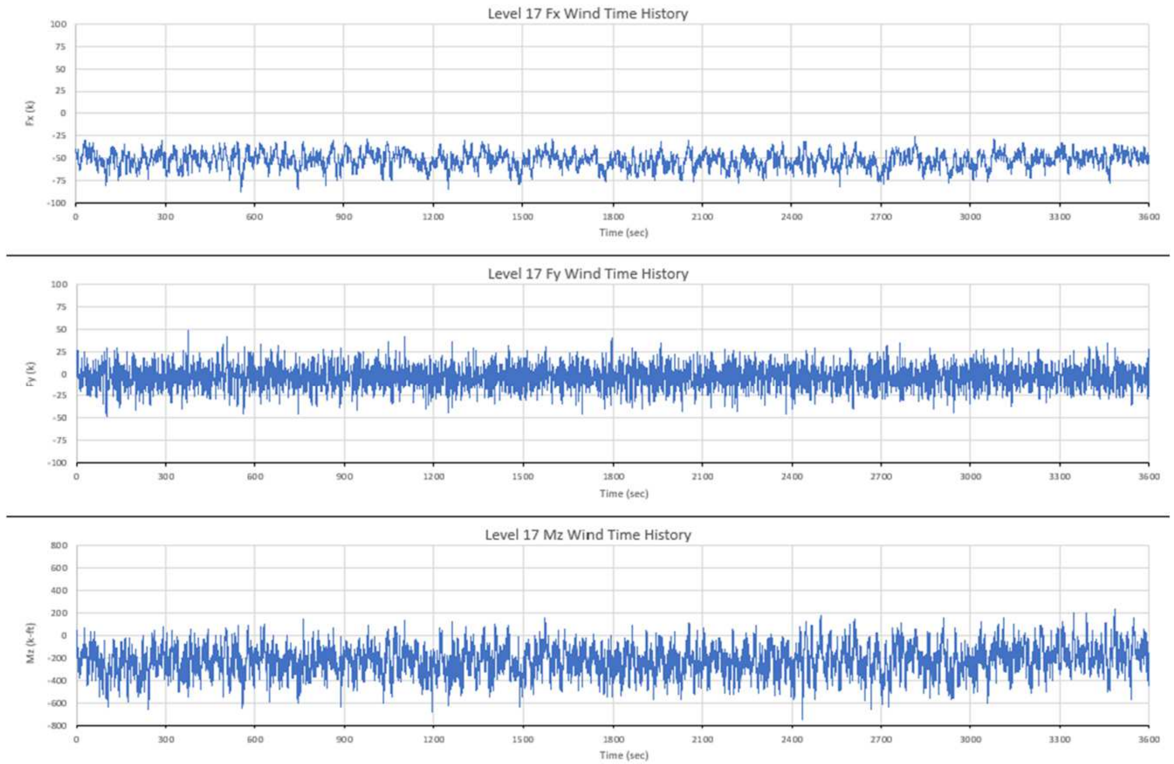
PBWD Analysis Example

DESIMONE

Performance Based Wind Design



Wind Time History Loading



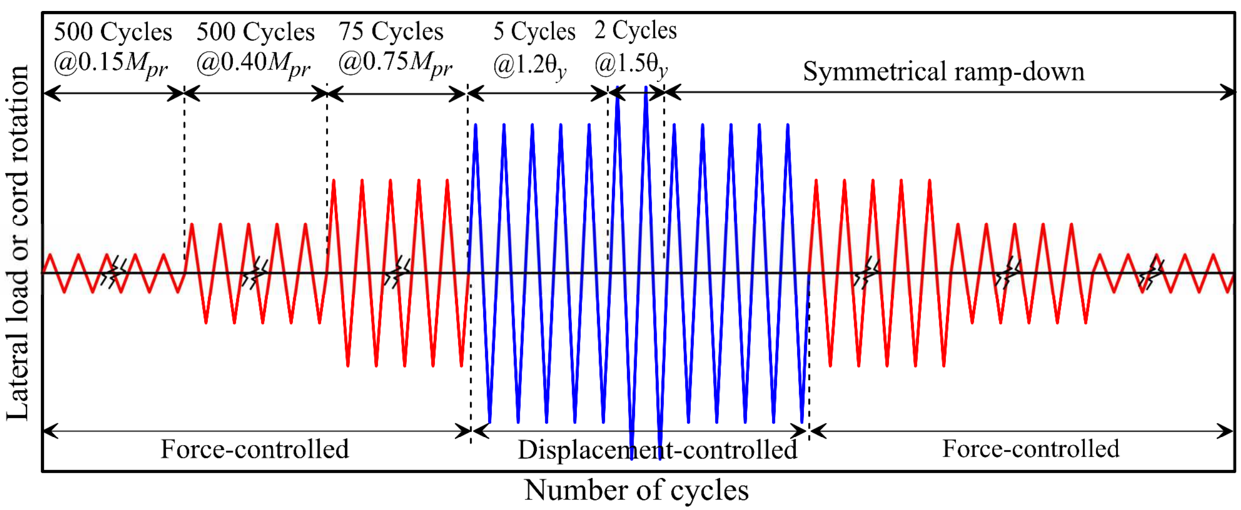
(3) Time Histories / Floor

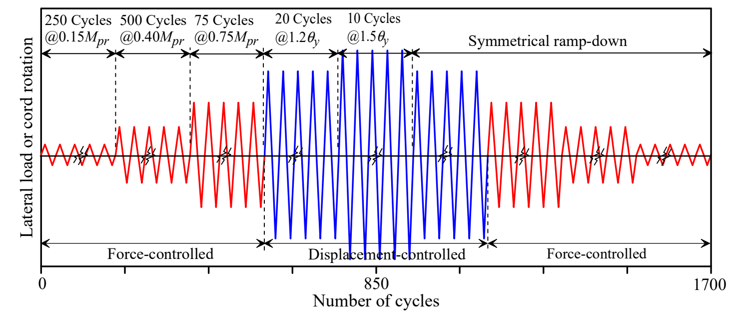
PBWD Analysis Example

DESIMONE

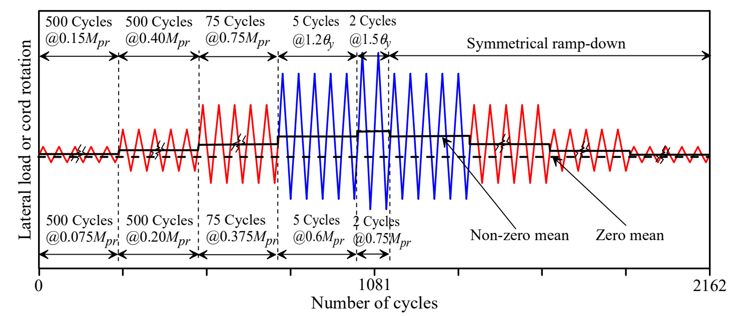
Calibration of Computer Models against Experimental Results

- "Experimental Study of Concrete Coupling Beams Subject to Wind and Seismic Loading Protocols," UCLA Report SEERL 2020/01 May 2020.
- Load protocol consisted of 2162 cycles
- Based on a building with 6s period (50-60 story) ≈ 3.5 hr storm

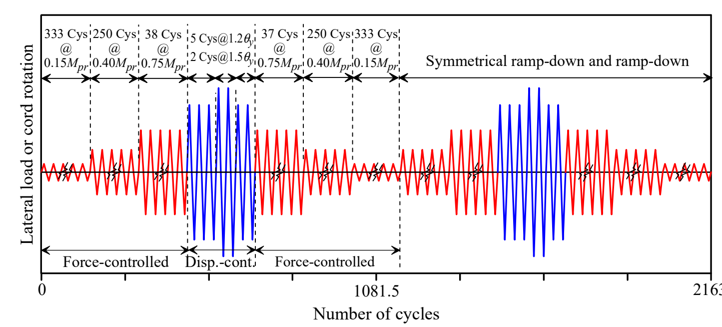




(a) Alternative wind loading protocol #1: More yielding cycles



(b) Alternative wind loading protocol #2: Non-zero mean



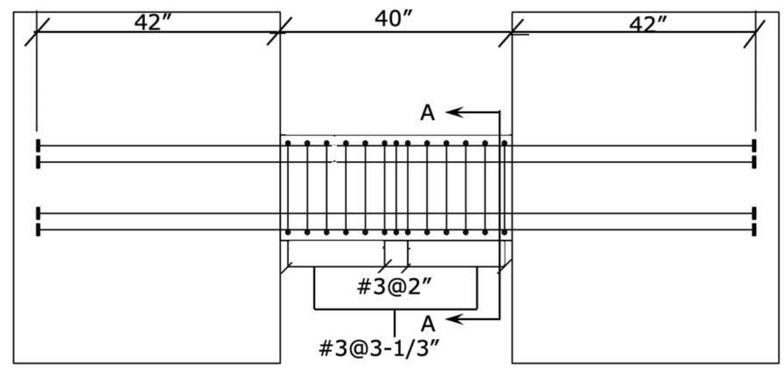
(c) Alternative wind loading protocol #3: Two ramp-up and ramp-downs

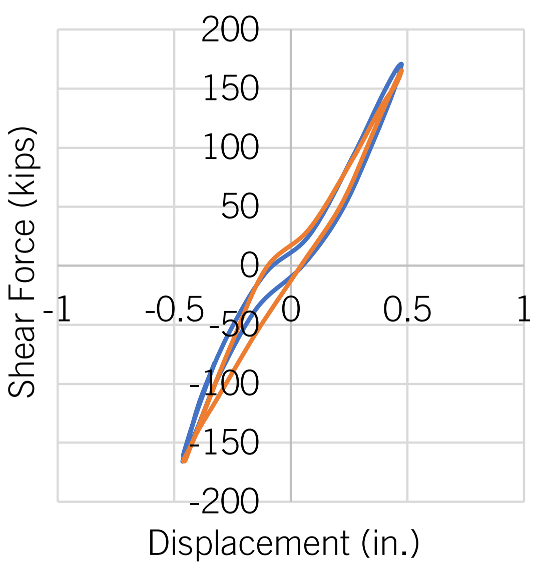
PBWD Analysis Example

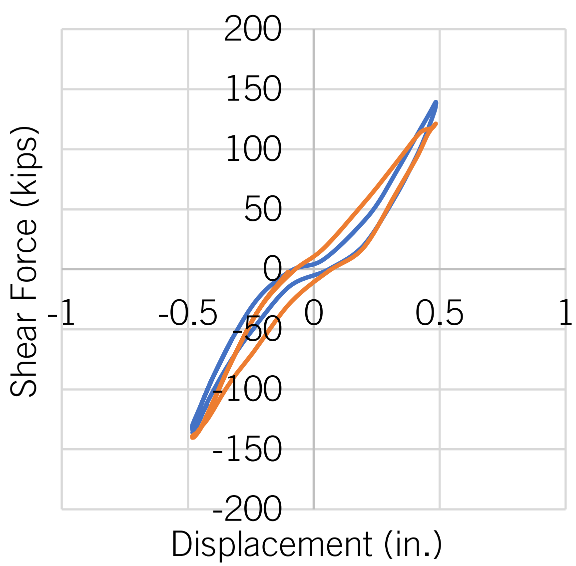
DESIMONE

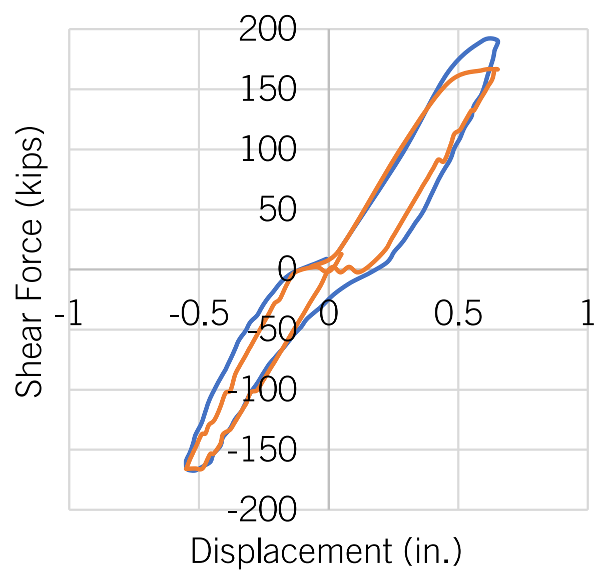
Calibration of Computer Models against Experimental Results

- DeSimone Calibration: ETABS Shear-Displacement Hinge Model, Beam Span/Depth = 2.5
- Currently in the processing of developing a NLTHA model







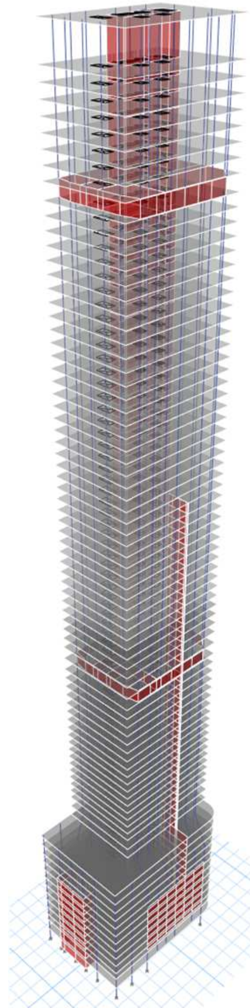


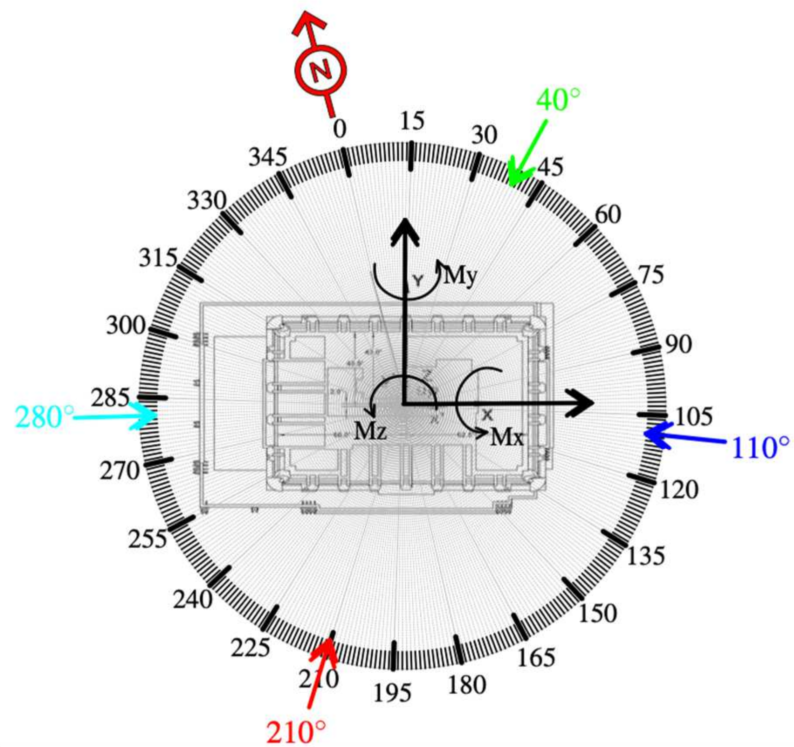
PBWD Analysis Example

DESIMONE

Example Linear Time History Analysis

- Structure "512B"
- 83 stories, 1000 ft
- Concrete shear walls, coupling beams and outriggers
- 700-year MRI wind speed V = 166 mph [74 m/s
- 3x Time Histories/floor per wind direction = 249 separate time histories
- (4) critical wind directions = 996 separate time histories
- DCE developed software for management





PBWD Analysis Example

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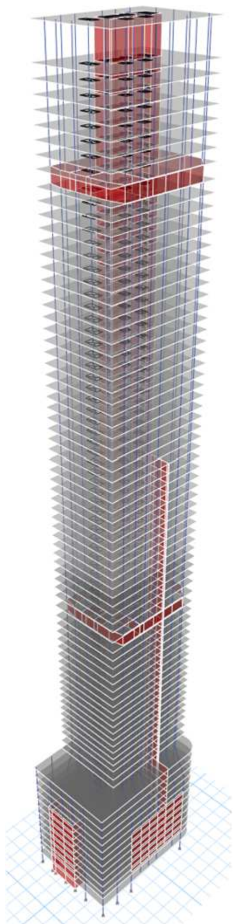
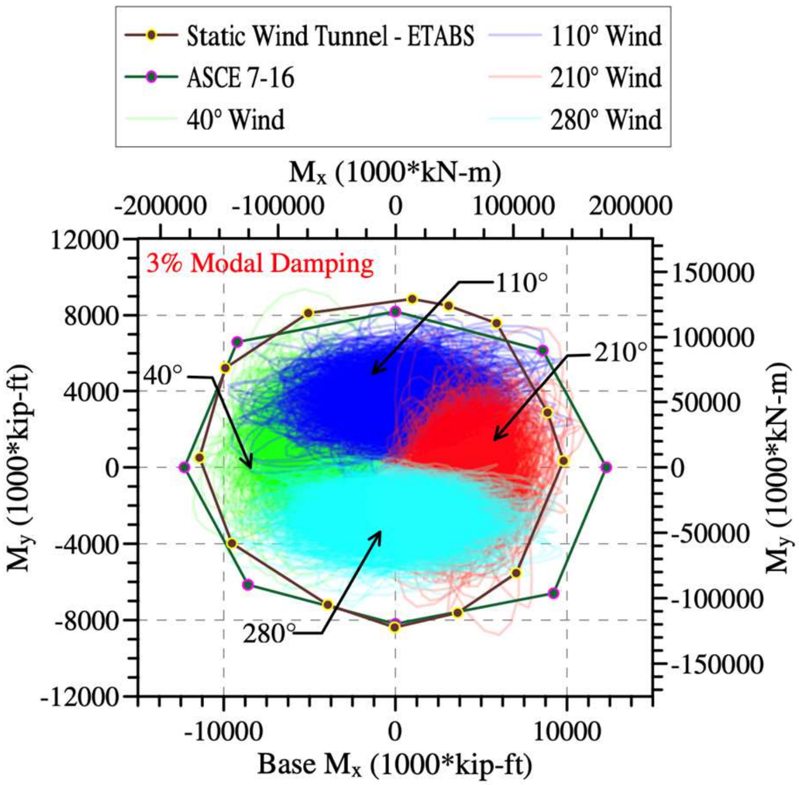
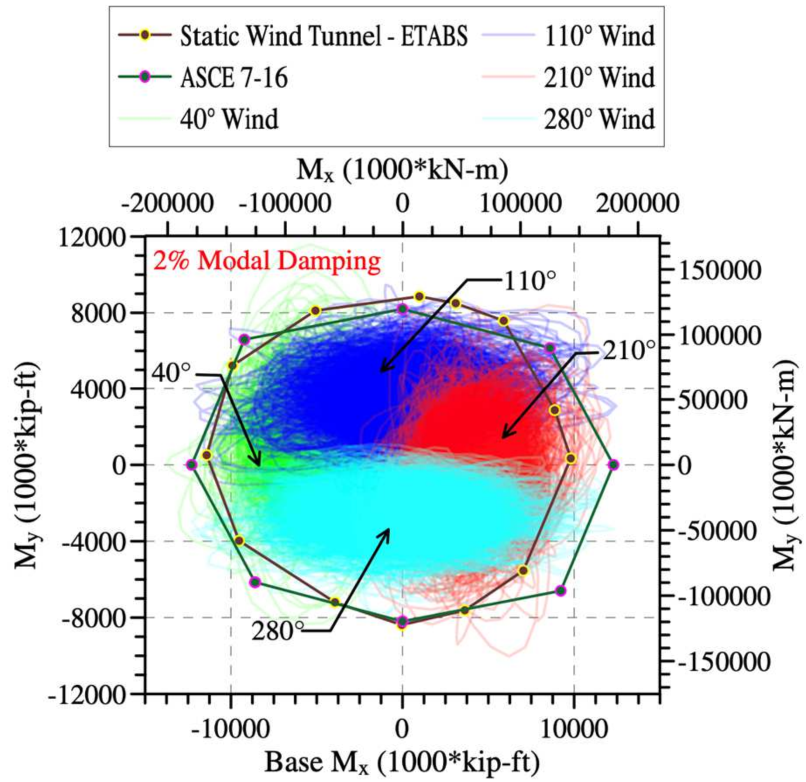
Effect of Assumed Damping



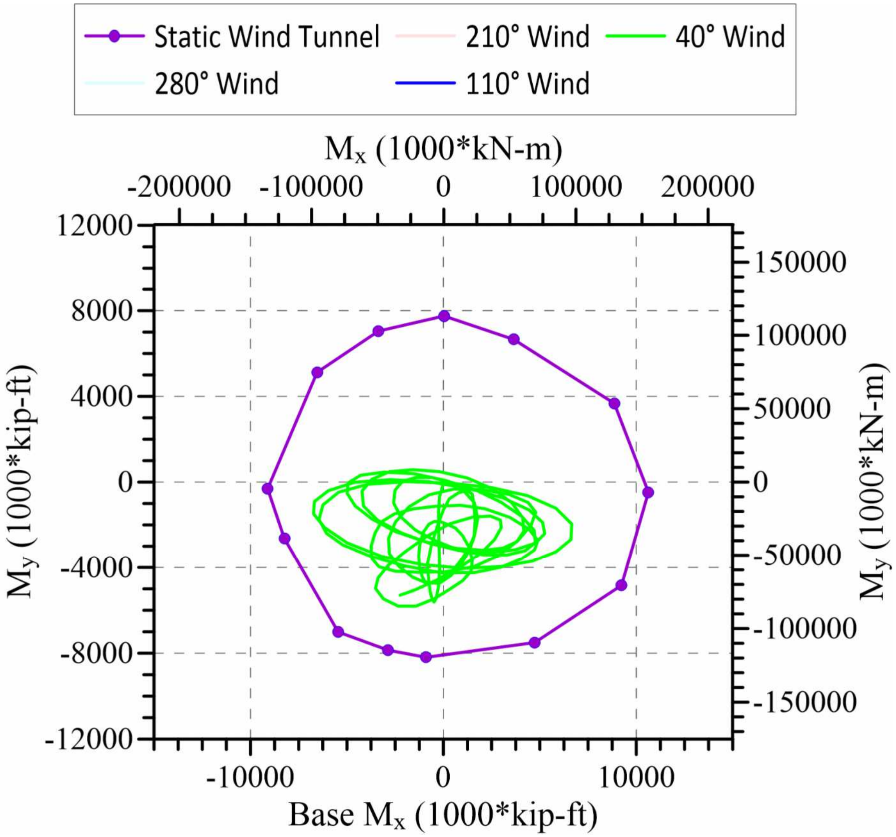


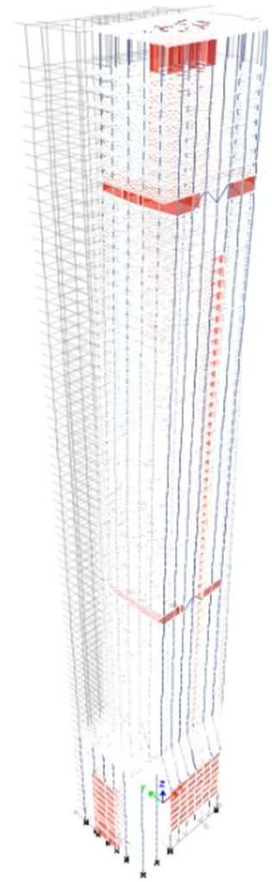


PBWD Analysis Example

DESIMONE

40° Wind Dynamic Response Animation





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5. SEI PBD Workshop March 4-5, 2025

SEI PBD Workshop

DESIMONE

SEI STRUCTURAL ENGINEERING INSTITUTE ASCE

GOAL and OUTCOME: *SEI Performance-Based Design Committee Leadership is to develop and execute a workshop to consider, examine, and set the direction for the profession in the use of performance-based design standards that will advance beyond our present-day prescriptive procedures.*

The outcome of the Workshop will be a Roadmap report to set the direction for SEI, and other ASCE Institutes, pertaining to the educational needs and prestandards needed to move performance-based design forward for the structural engineering profession for the next 10 years.

PBD Categories

Building Seismic

Building Wind

Building Fire

Non-Building Structures

Bridges

Questions to Answer

DESIMONE

1. Where do you envision PBD to be in 10 years?
2. What is the benefit of using PBD on your project?
3. What barriers are you seeing in PBD use to get to the finish line?
4. What is needed to get to the 10-year vision?
5. What forms of education do we need to do to promote PBD?
6. What are the top five priorities for moving PBD into practice in the next 10 years?

Results and Takeaways

DESIMONE

This slide has been REDACTED pending the publication of the approved:

STRUCTURAL ENGINEERING INSTITUTE

SEI Performance-Based Design Workshop

March 4th & 5th, 2025

DESIMONE

The End