FEMA P-807
Guidelines for Seismic Retrofit of Weak-Story Wood-Frame Buildings

Post-Northridge Developments

Large Scale Response History Analysis

FEMA P-695 : Incremental Dynamic Analysis

Testing of Archaic Materials

Design of Perforated Walls

FEMA P-807 Innovations

Relative Strength Method

Surrogate Structure Matching

Weak Story Tool

4,400 Dangerous Multi-unit Buildings: 8% of population

Create Seismic Retrofit Program for
Weak-Story Wood-framed Apartment Buildings
in Western US

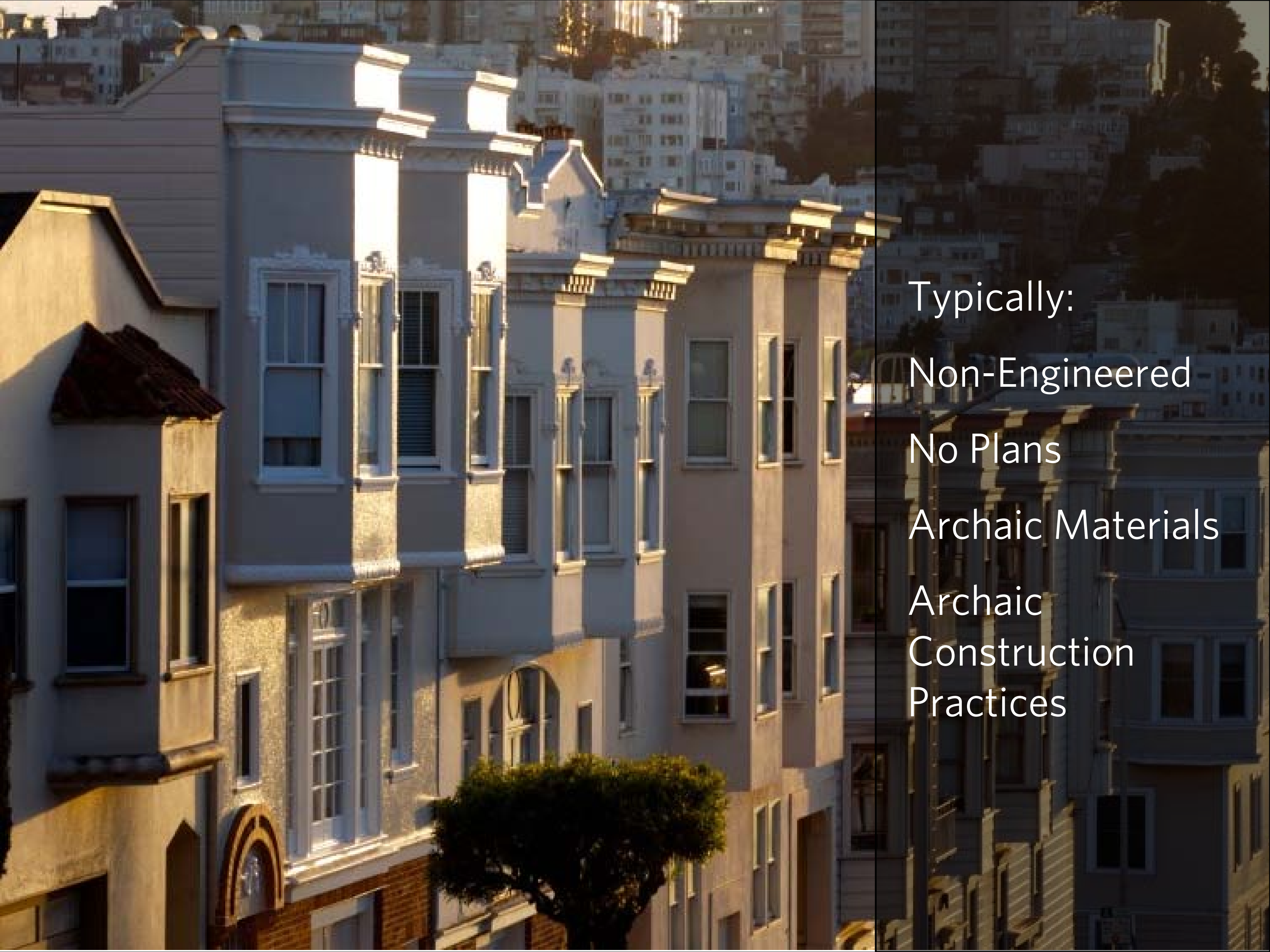
The Problem

1989 Loma Prieta earthquake
Image by Raymond B. Seed
National Information Service for Earthquake Engineering
University of California, Berkeley.

Inexpensive to Construct
(Work Only In Ground Story)

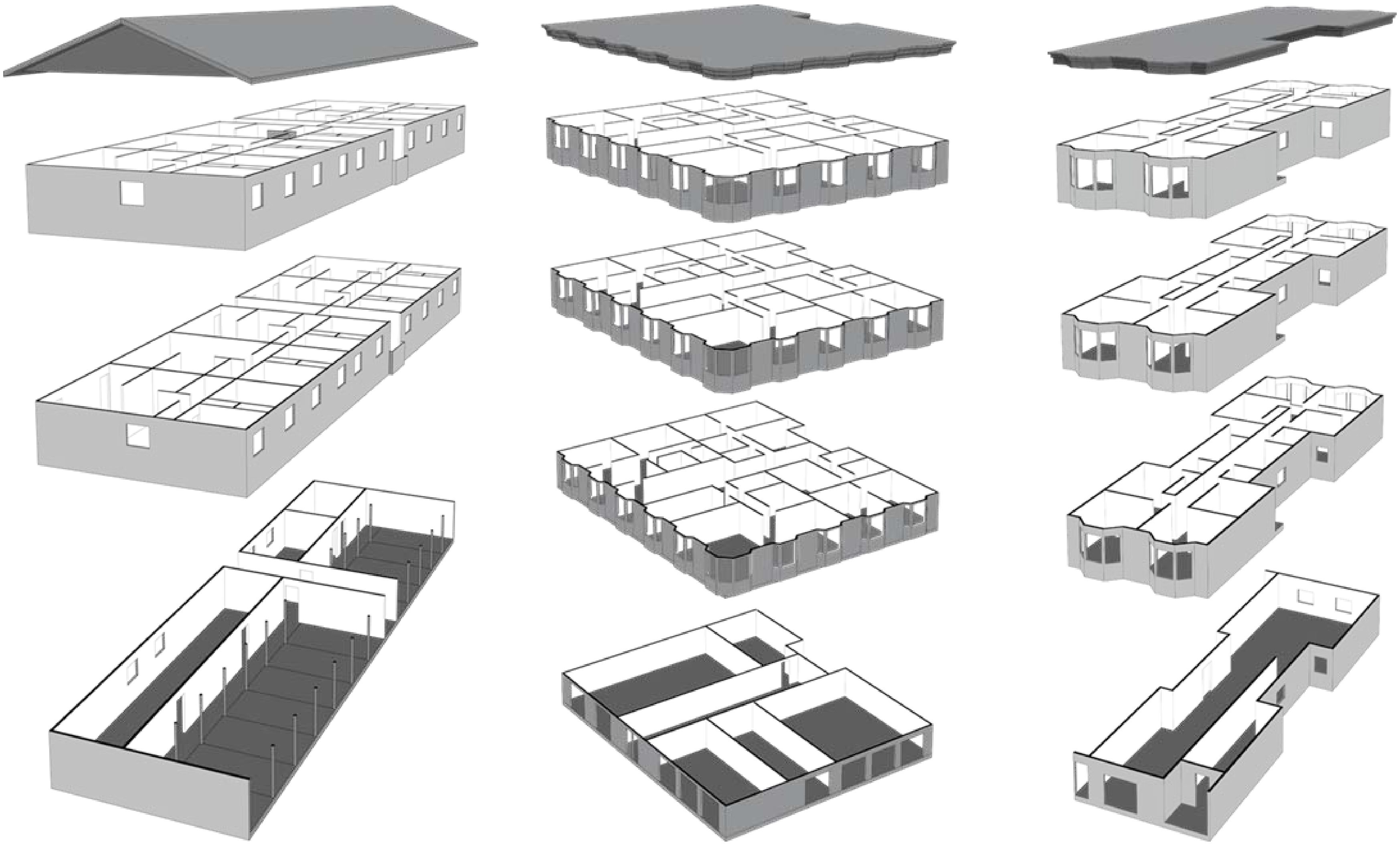
Inexpensive to Design
(Unsophisticated Engineers)

Performs Well
(Shelter-In-Place)


Typically:
Non-Engineered
No Plans
Archaic Materials
Archaic Construction Practices

Design for a Population of Buildings, not an Individual Building

Pattern Recognition



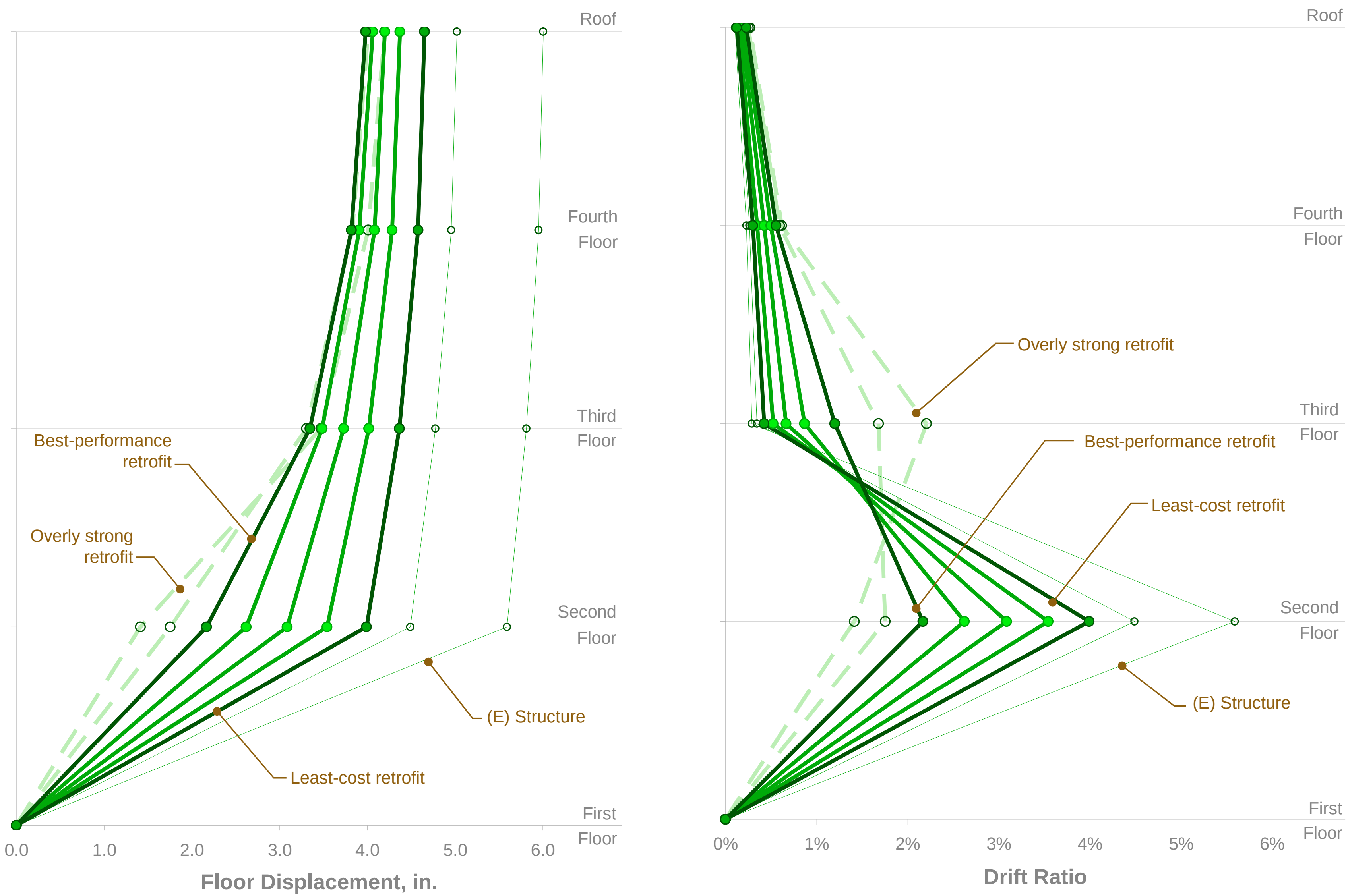
Pattern Recognition

Limited Damage to Upper Structure

Damage Concentrated in Lower Structure

RELATIVE STRENGTH METHOD

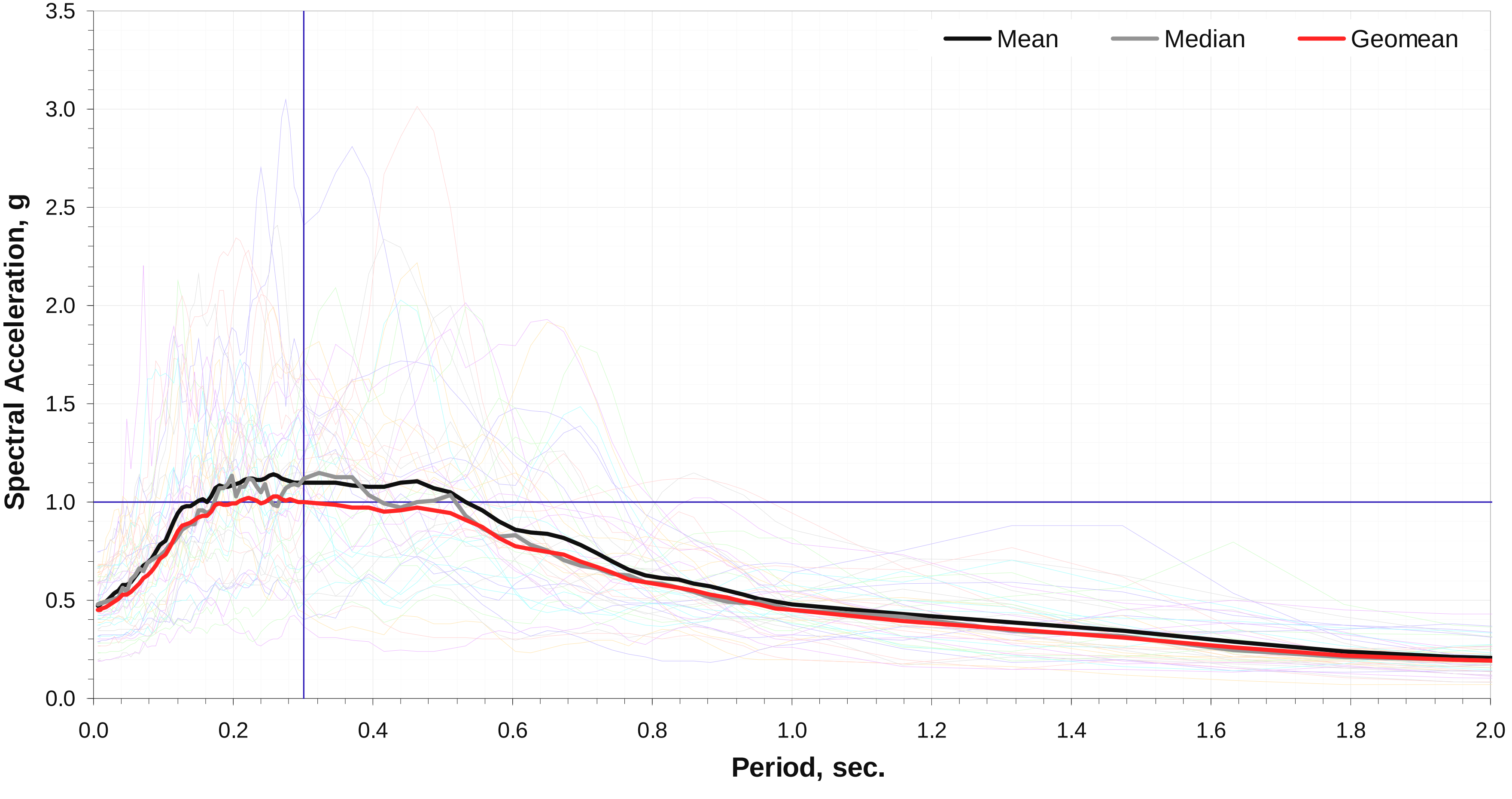
The Relative Strength Method



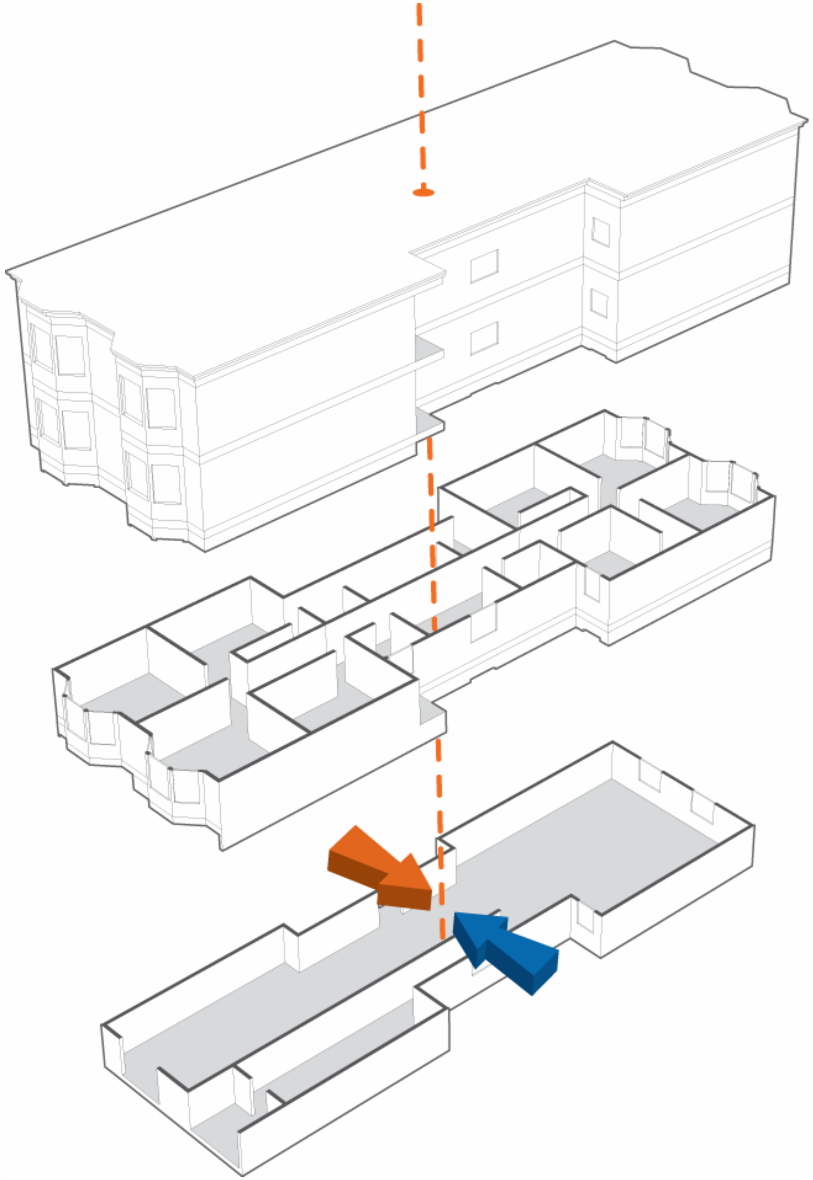
SURROGATE STRUCTURE MATCHING

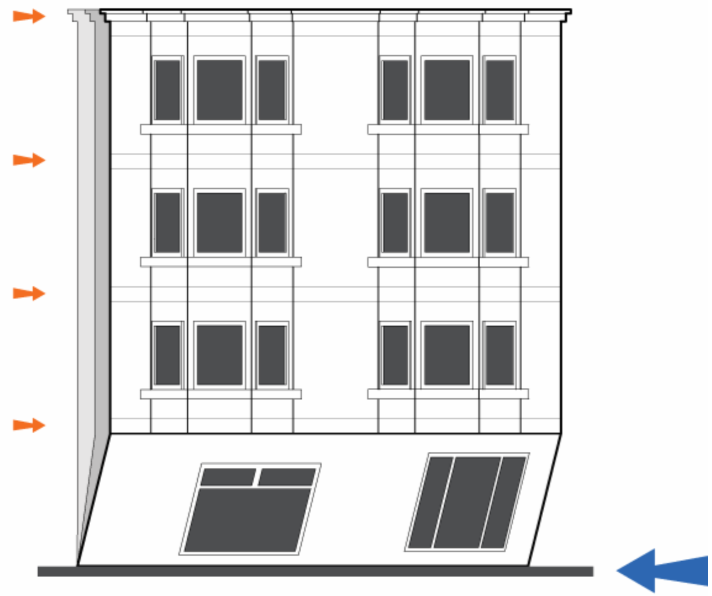
Can a Building's Capacity be Determined from a Few Parameters?

Local Seismicity

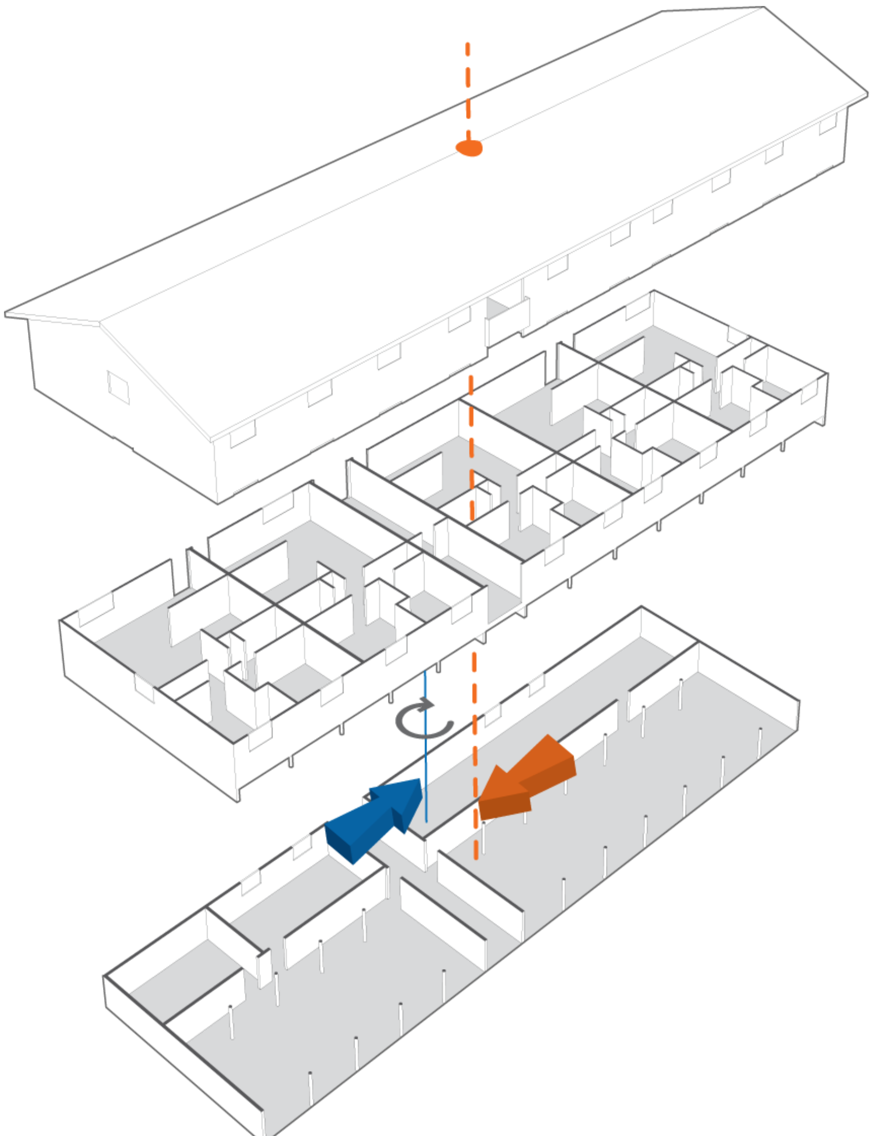


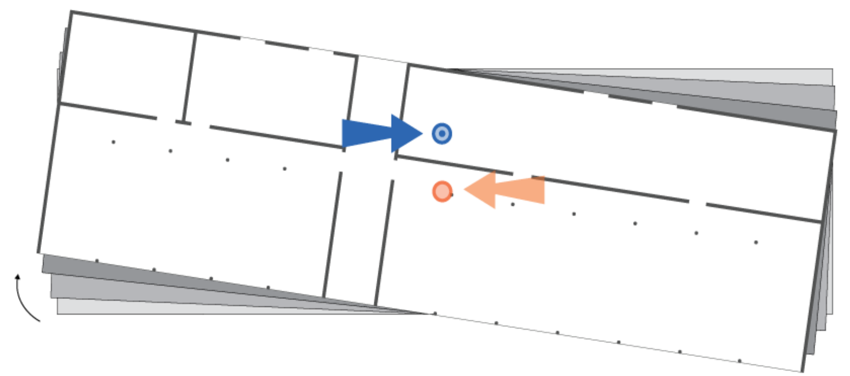
Translational Weakness



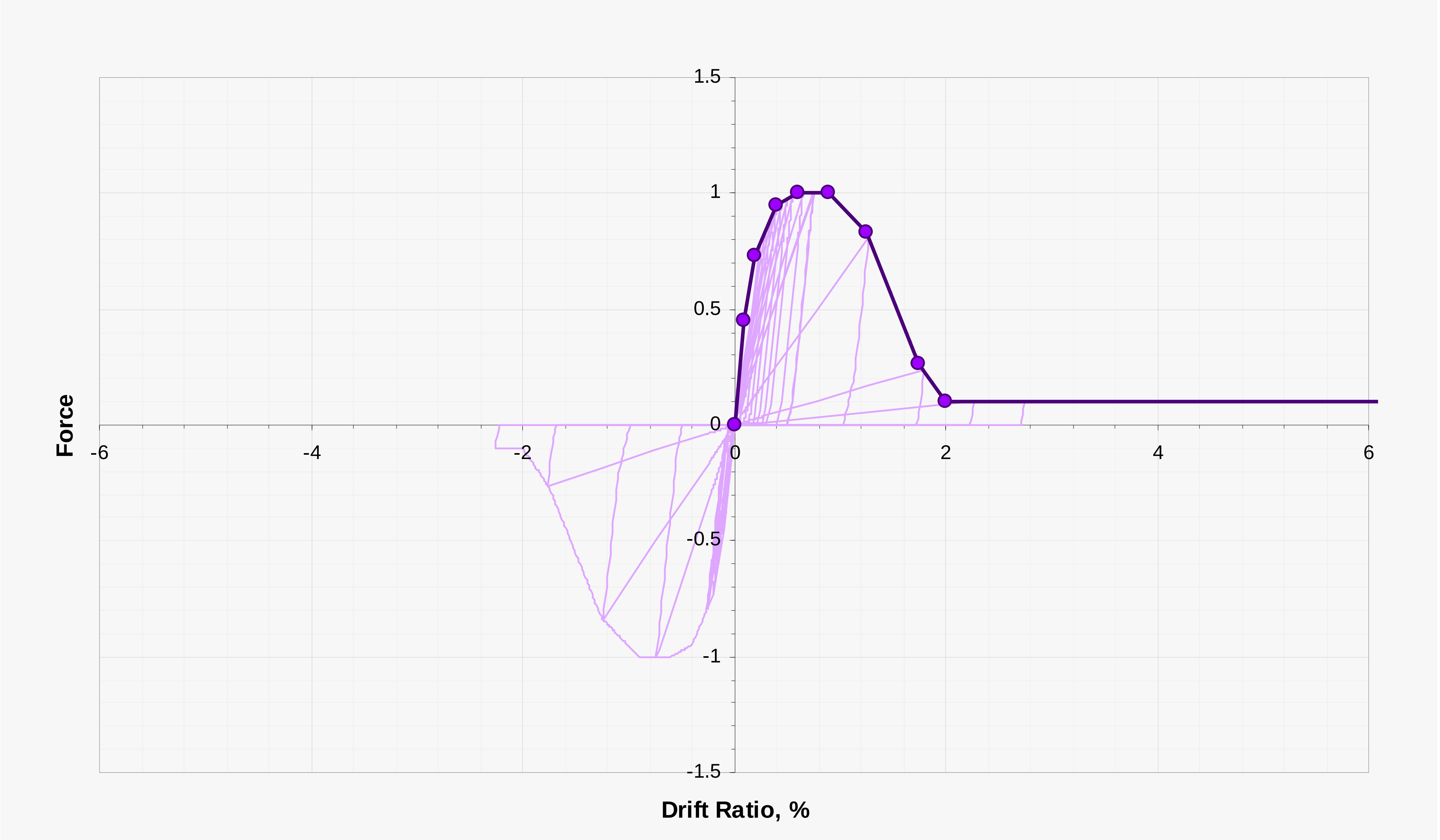


Torsional Weakness



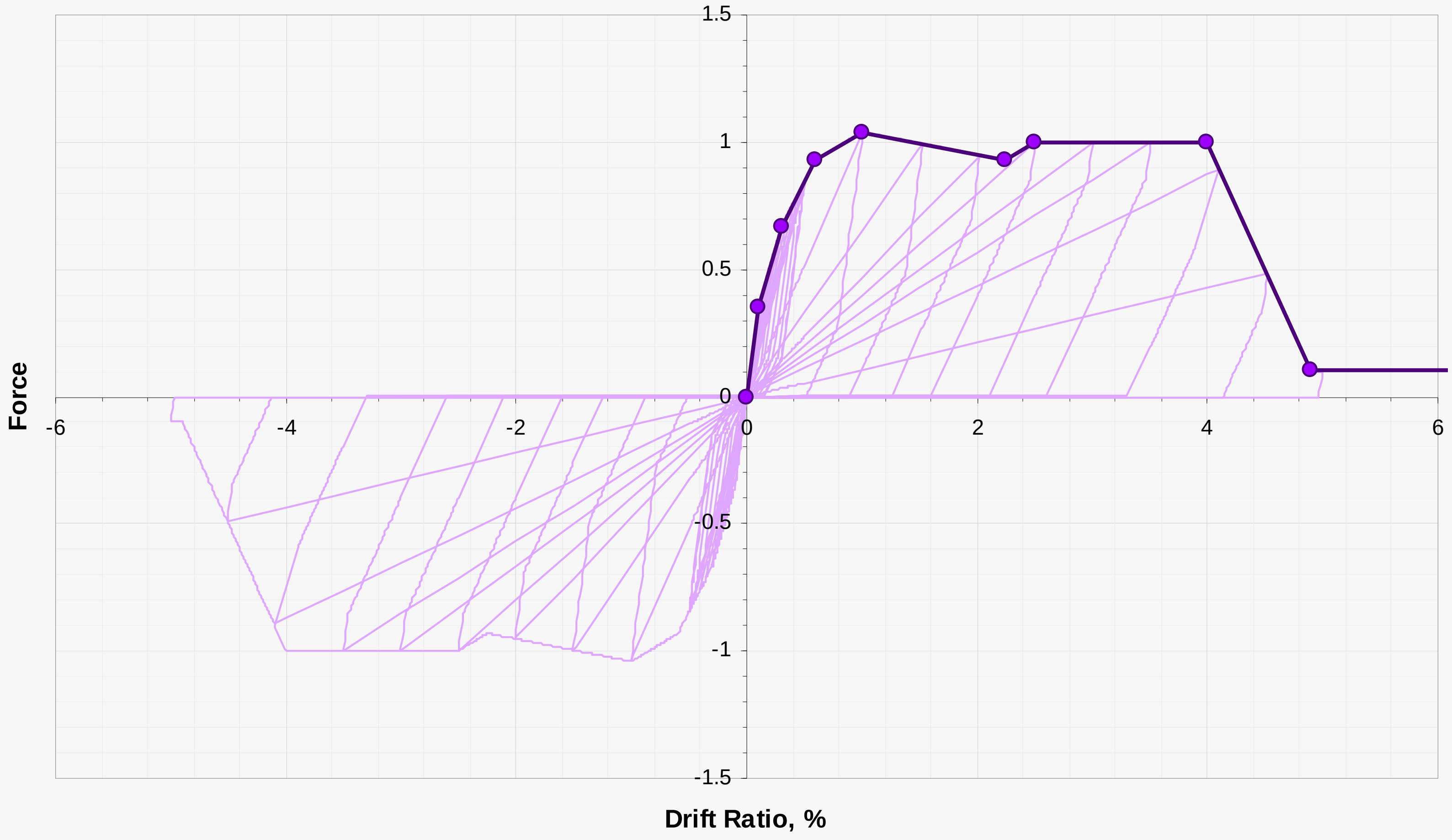


Low Displacement Capacity



Hysteresis of low displacement capacity material

High Displacement Capacity

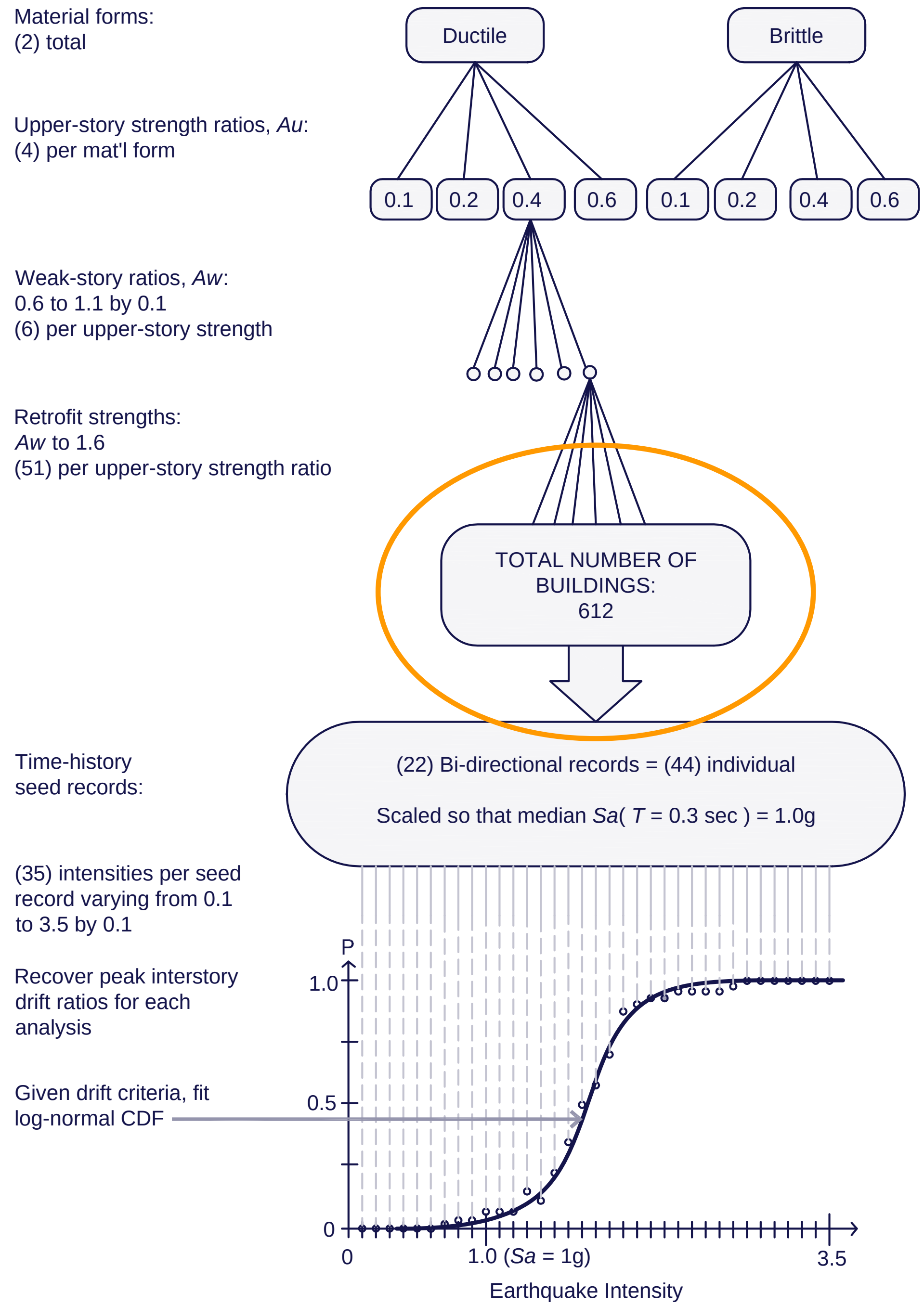


Hysteresis of high-displacement capacity material

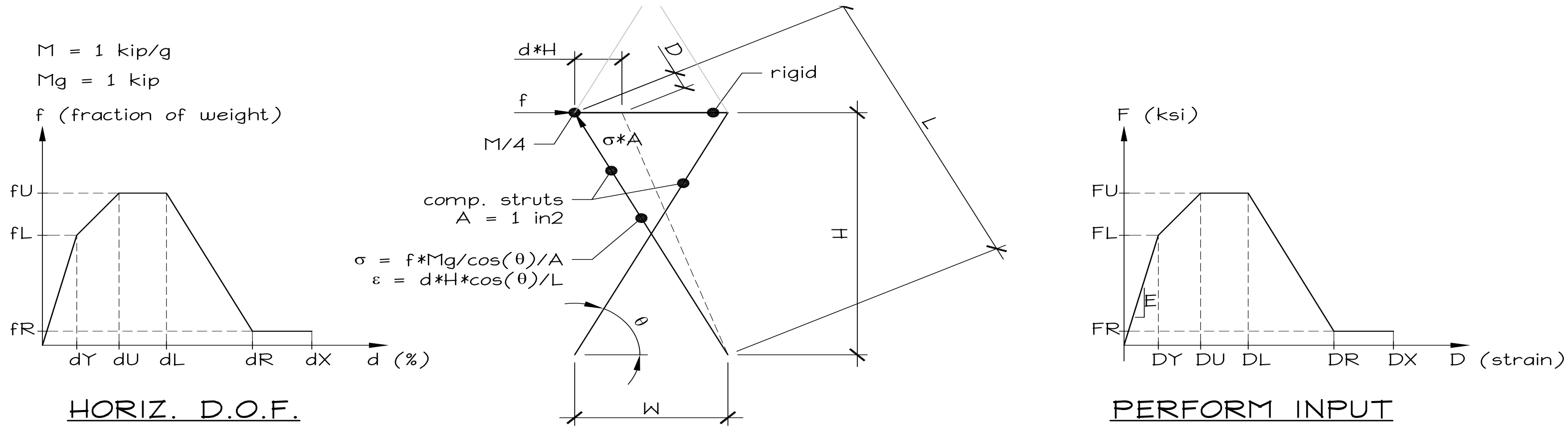
Create a Controlled Experiment

Determine the Influence of Each Characteristic

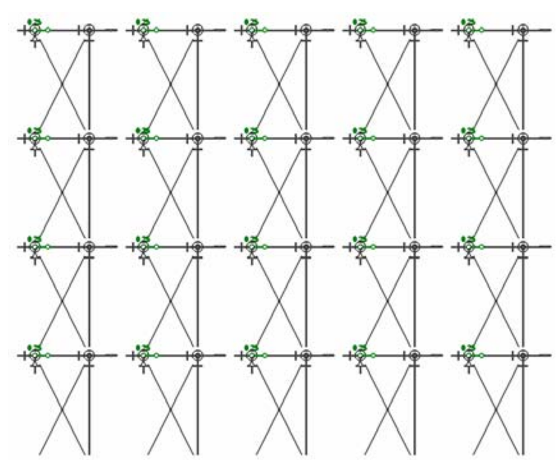
Analytical Engine: Surrogate Structure Concept



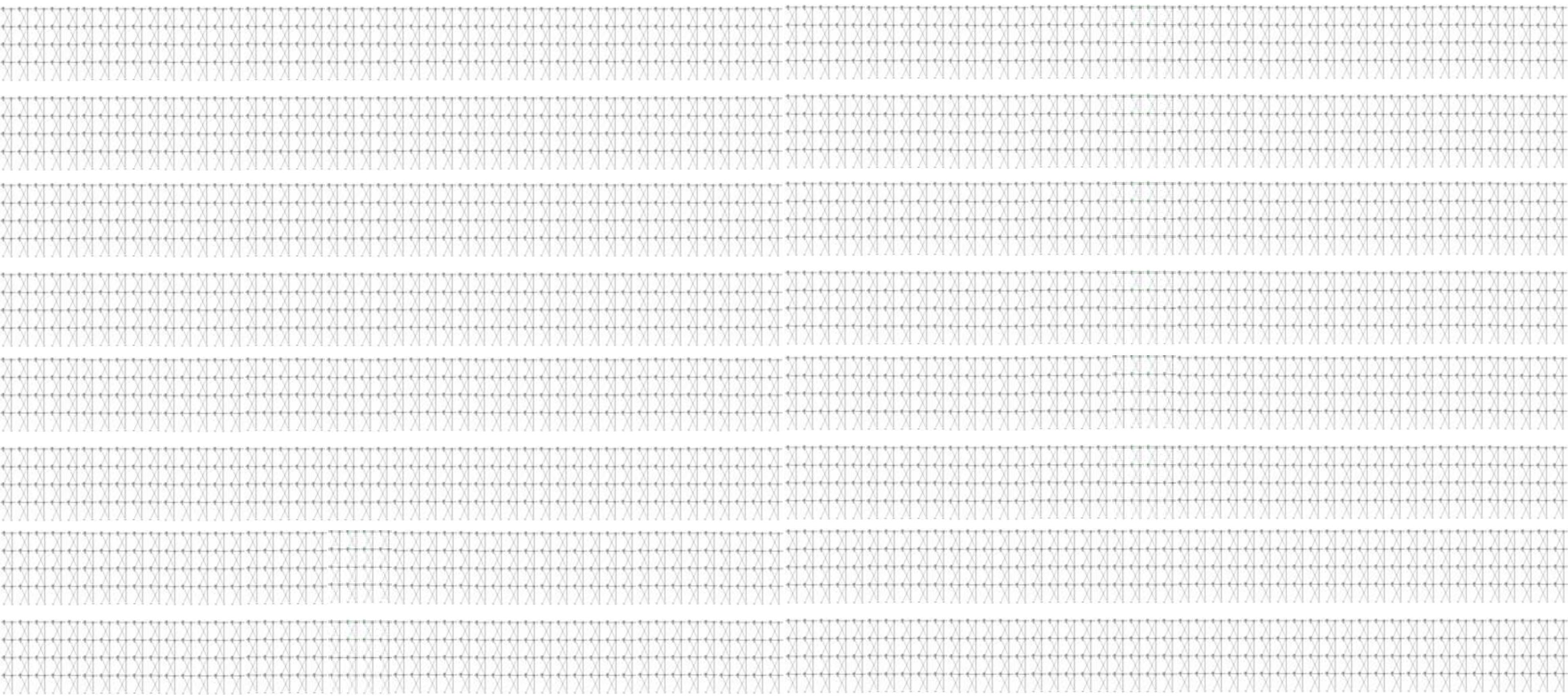
Simplified Building Model



W	50	in.	
H	100	in.	
L	111.8		
q	1.107	rad,	
	63.4	deg.	
cos(q)	0.447		
Astrut	1	in2	
Mg	1	kip	(total weight of building)



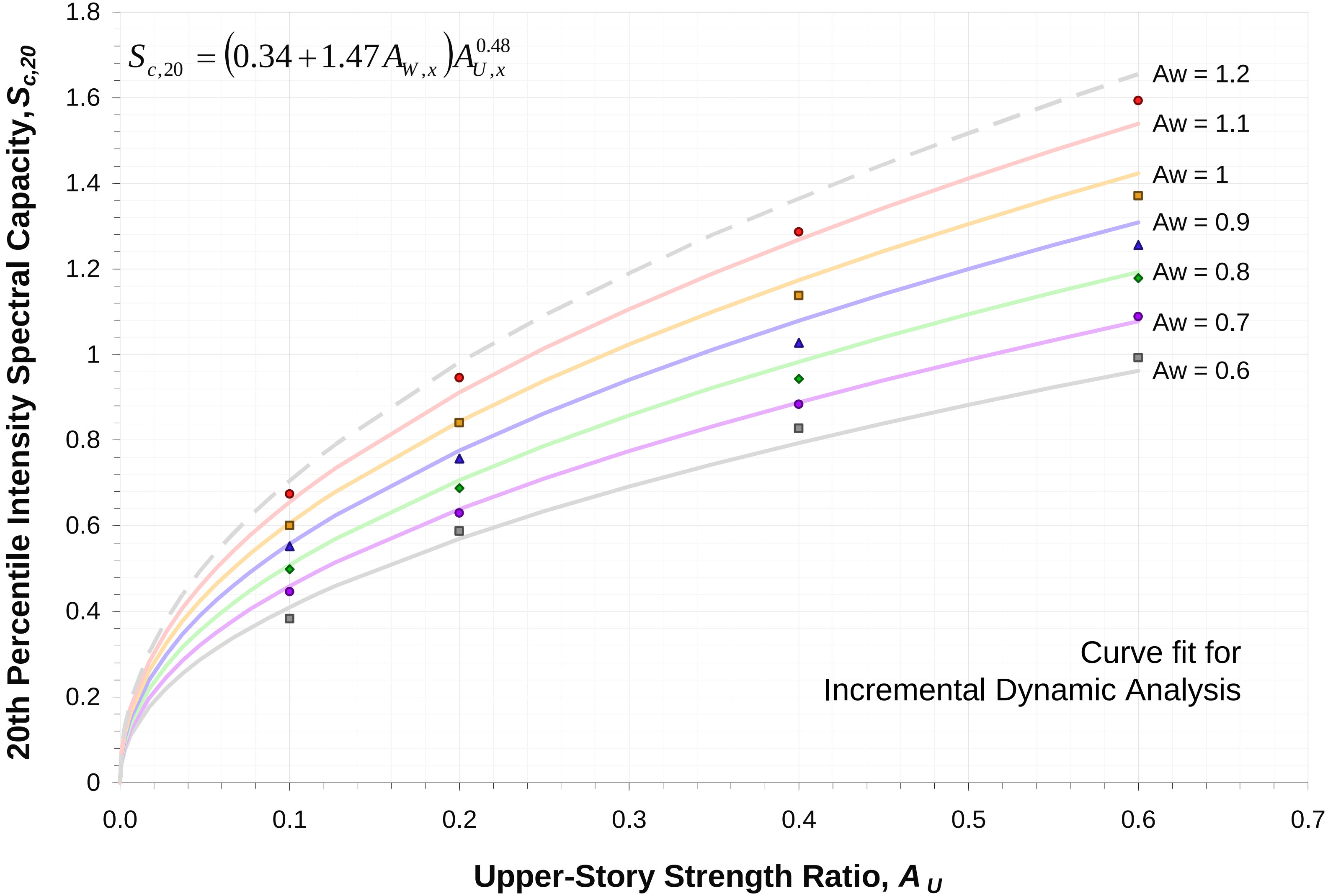
Analytical Engine:
Surrogate-Structure Concept



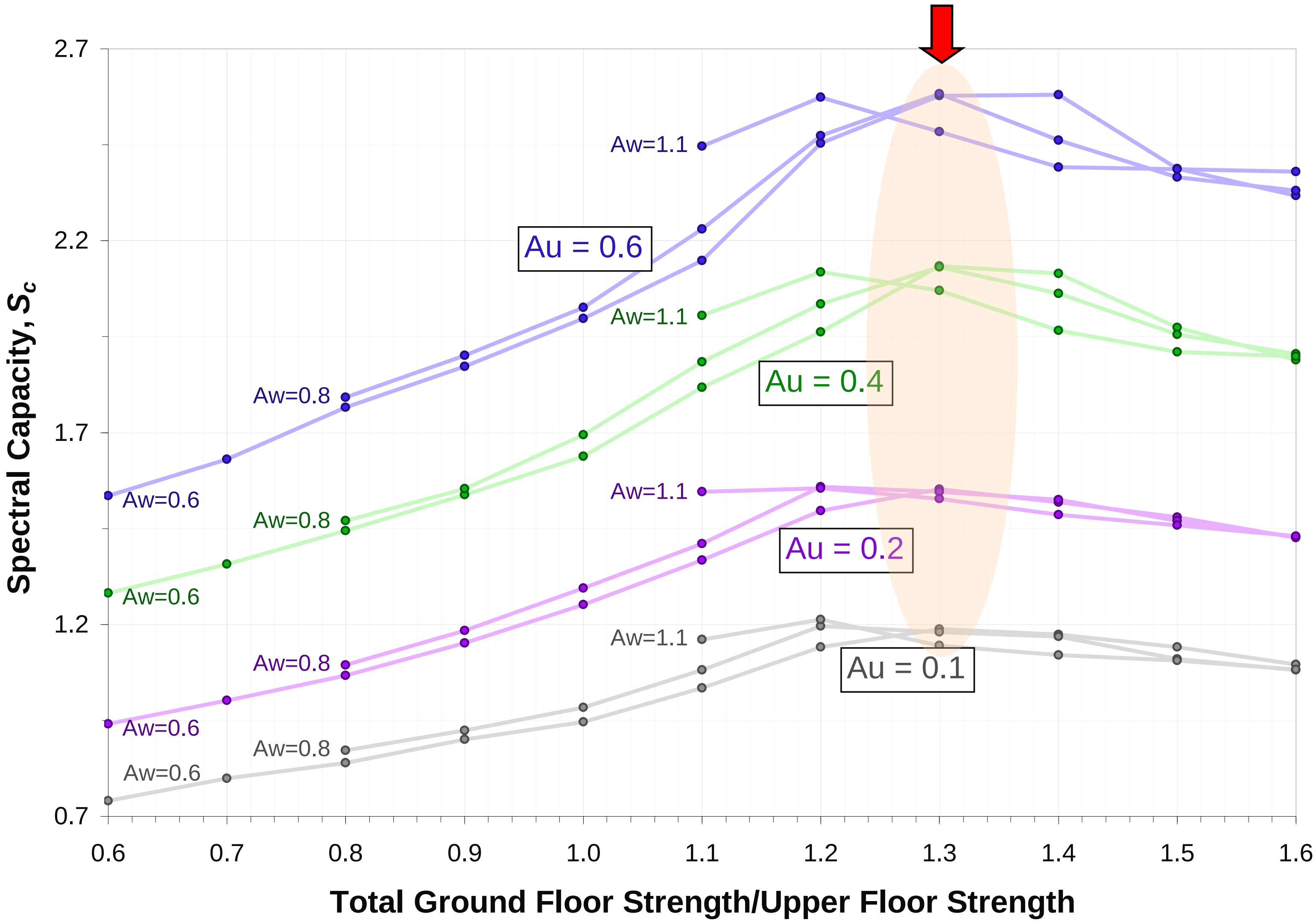
612 surrogate structures x 44 EQs x 35 intensities

1 million nonlinear response-history analyses

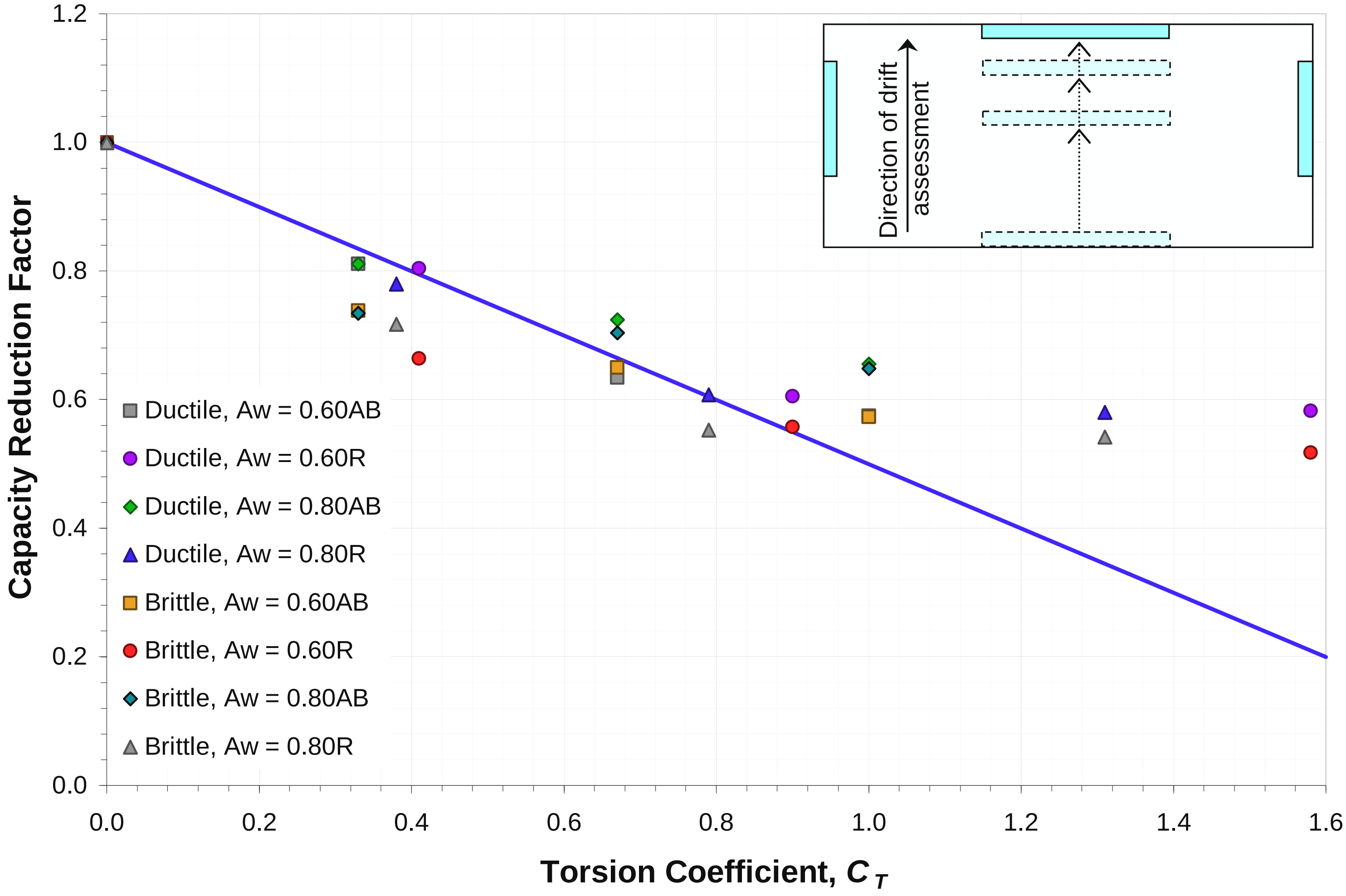
Analysis Results



Analysis Results



Analytical Methodology – Accounting for Torsion



Spectral Capacity, Sc

$$S_{c1,x} = 0.66\left(0.525 + 2.24A_{W,x}\right)\left(1 - 0.5C_T\right)Q_s A_{U,x}^{0.48}$$ $C_D = 1.0$

$$S_{c0,x} = 0.60\left(0.122 + 1.59A_{W,x}\right)\left(1 - 0.5C_T\right)Q_s A_{U,x}^{0.60}$$ $C_D = 0.0$

Modifier for *POE* = 0.2

Mean spectral capacity, S_m

$$S_{c,x} = C_D^3 S_{c1,x} + \left(1 - C_D^3\right)S_{c0,x}$$ for intermediate values

$$S_{c,x} \geq S_{MS}$$ if true - no retrofit required

Onset of Strength Loss drift criteria, OSL

20% Probability of Exceedance, POE

Characteristic Structural Coefficients

Ground-story Strength $$C_{s,x} = \frac{V_{1,x}}{\sum_{j=1}^{N_s} W_j}$$

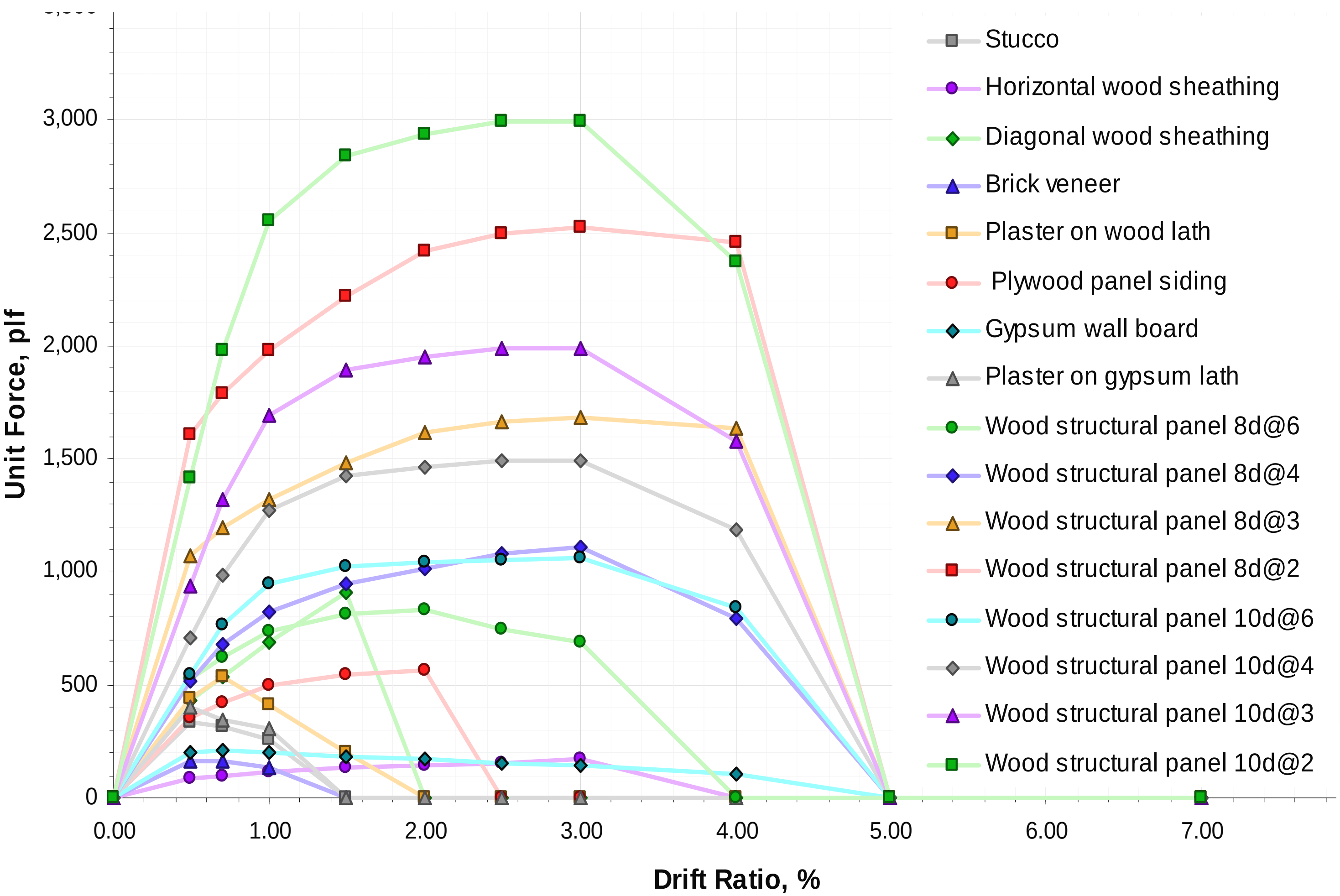
Upper-story Strength $$C_{U,x} = \min\left(\frac{V_{i,x}}{\sum_{j=i}^{N_s} W_j}\right)_{i=2\rightarrow N_s}$$

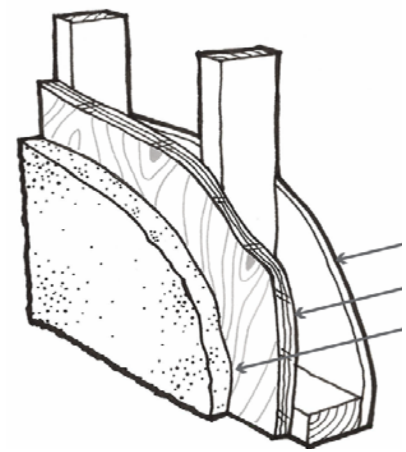
Upper to Ground Strength Ratio $$C_{W,x} = \frac{C_{s,x}}{C_{U,x}}$$

Toughness $$C_{D,x} = \frac{F_{1,x}(\delta = 3\%)}{V_{1,x}}$$

Torsional Imbalance $$C_T = \frac{\tau}{T}$$

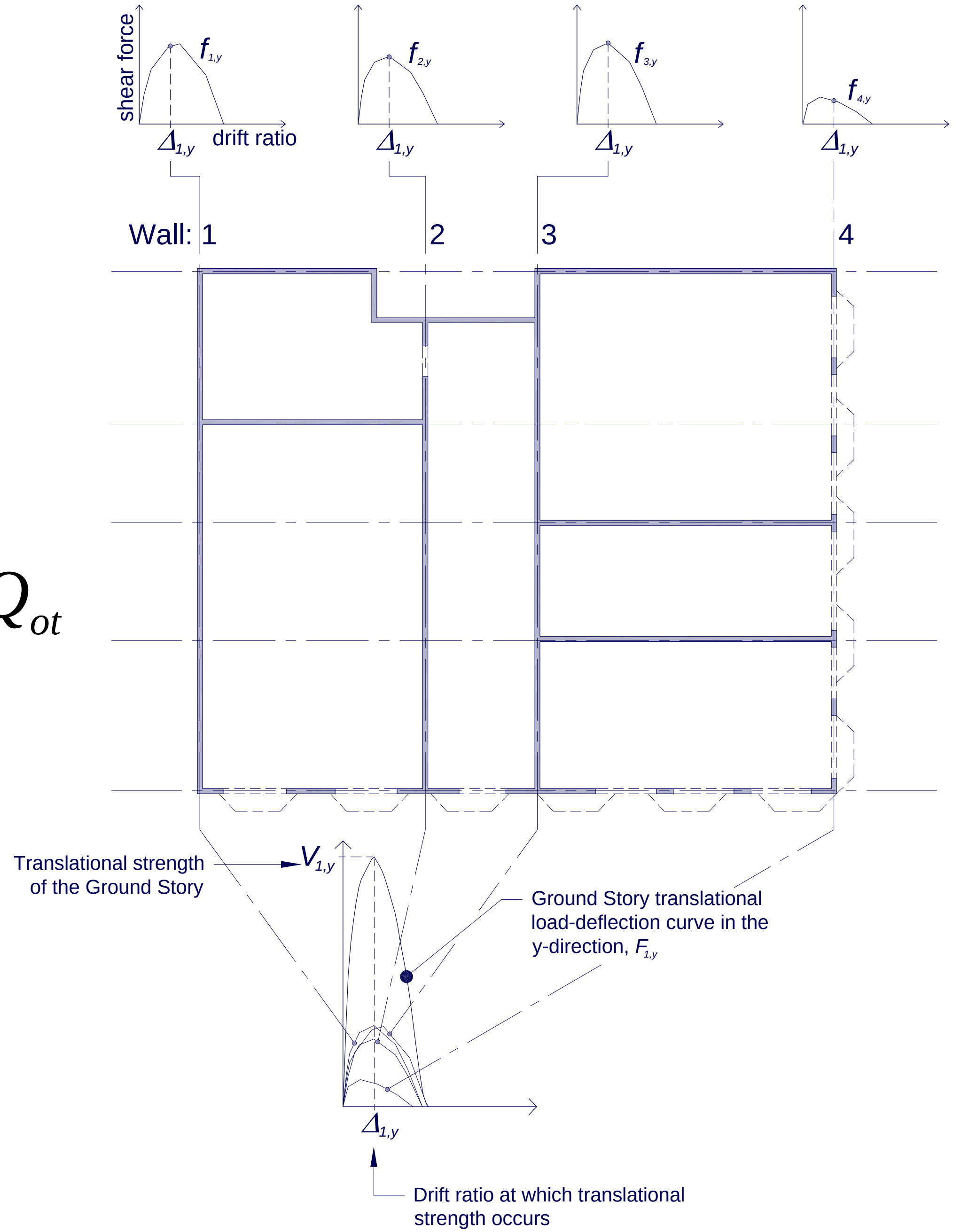
Structural Use of Non-conforming Materials



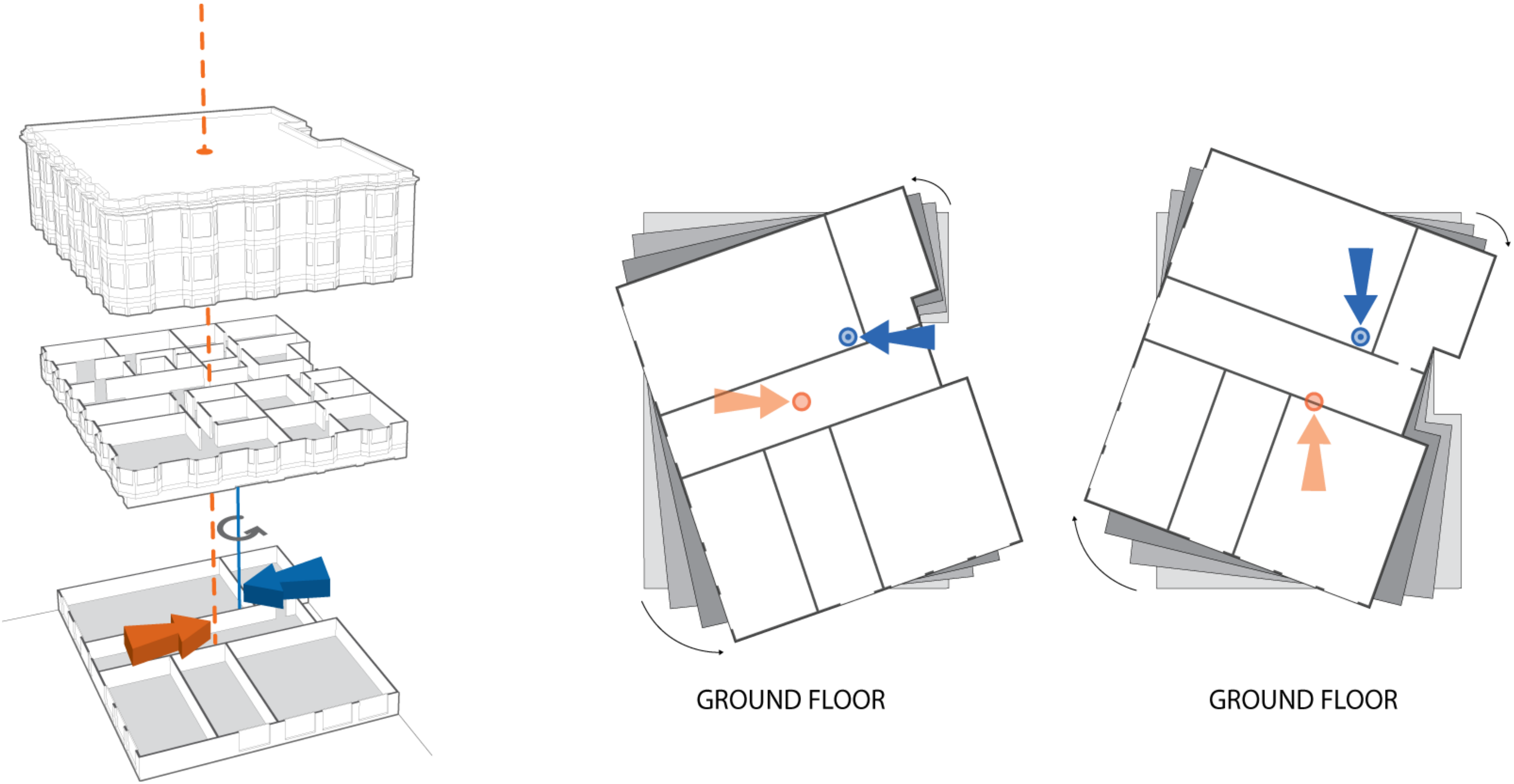


Pushover Curve to Find Peak Strength

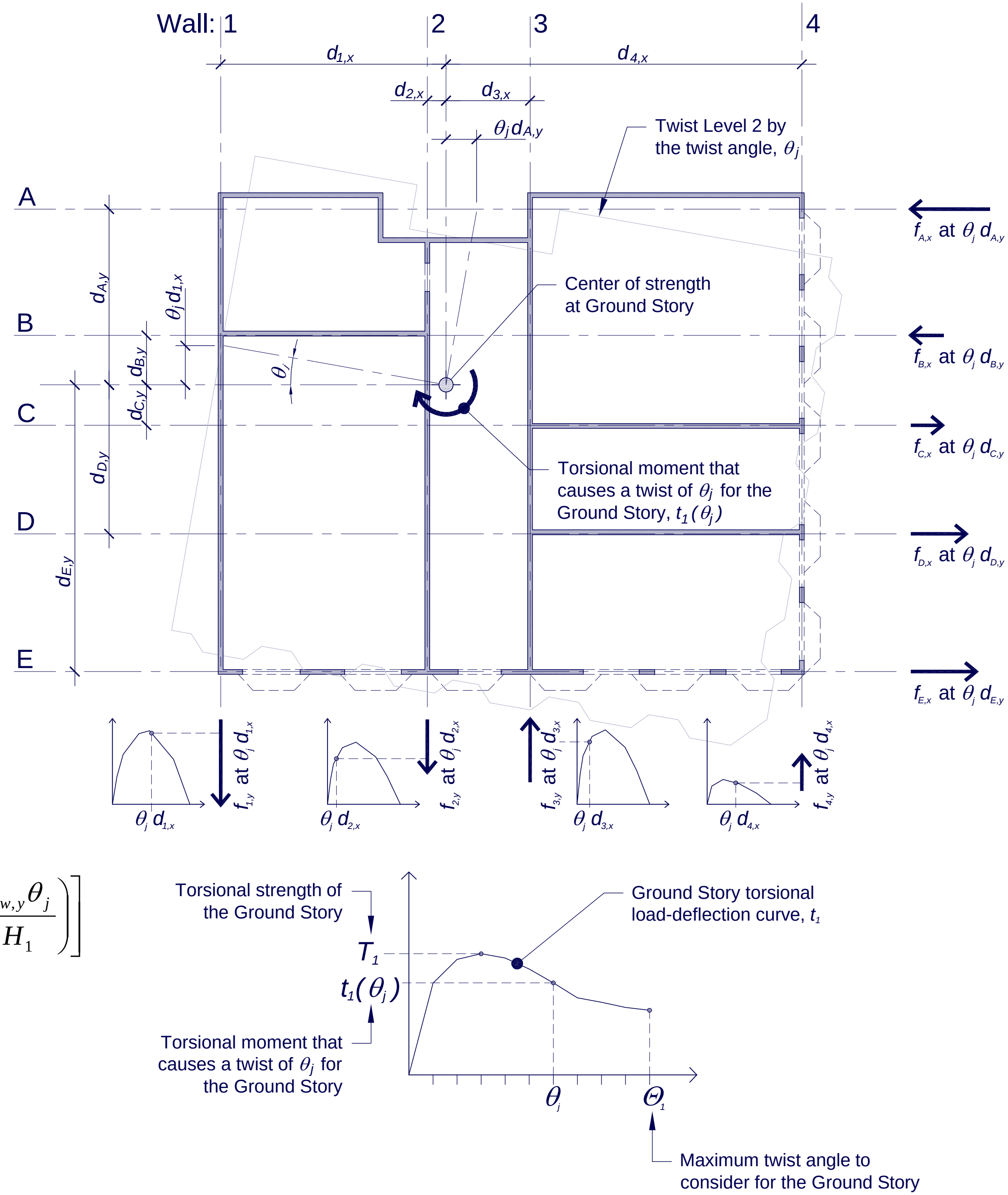
$$f_w(\delta_j) = v_w(\delta_j) L_w Q_{perf} Q_{ot}$$



Weak-Story Wood-Frame Buildings



Torsion Backbone Curve



$$t(\theta_j) = \sum_{w=1}^{N_{walls}} \left[d_{w,y} f_{w,x}\left(\frac{d_{w,y}\theta_j}{H_1}\right) + d_{w,x} f_{w,y}\left(\frac{d_{w,y}\theta_j}{H_1}\right)\right]$$

$$T = \max\left|t(\theta_j)\right|$$

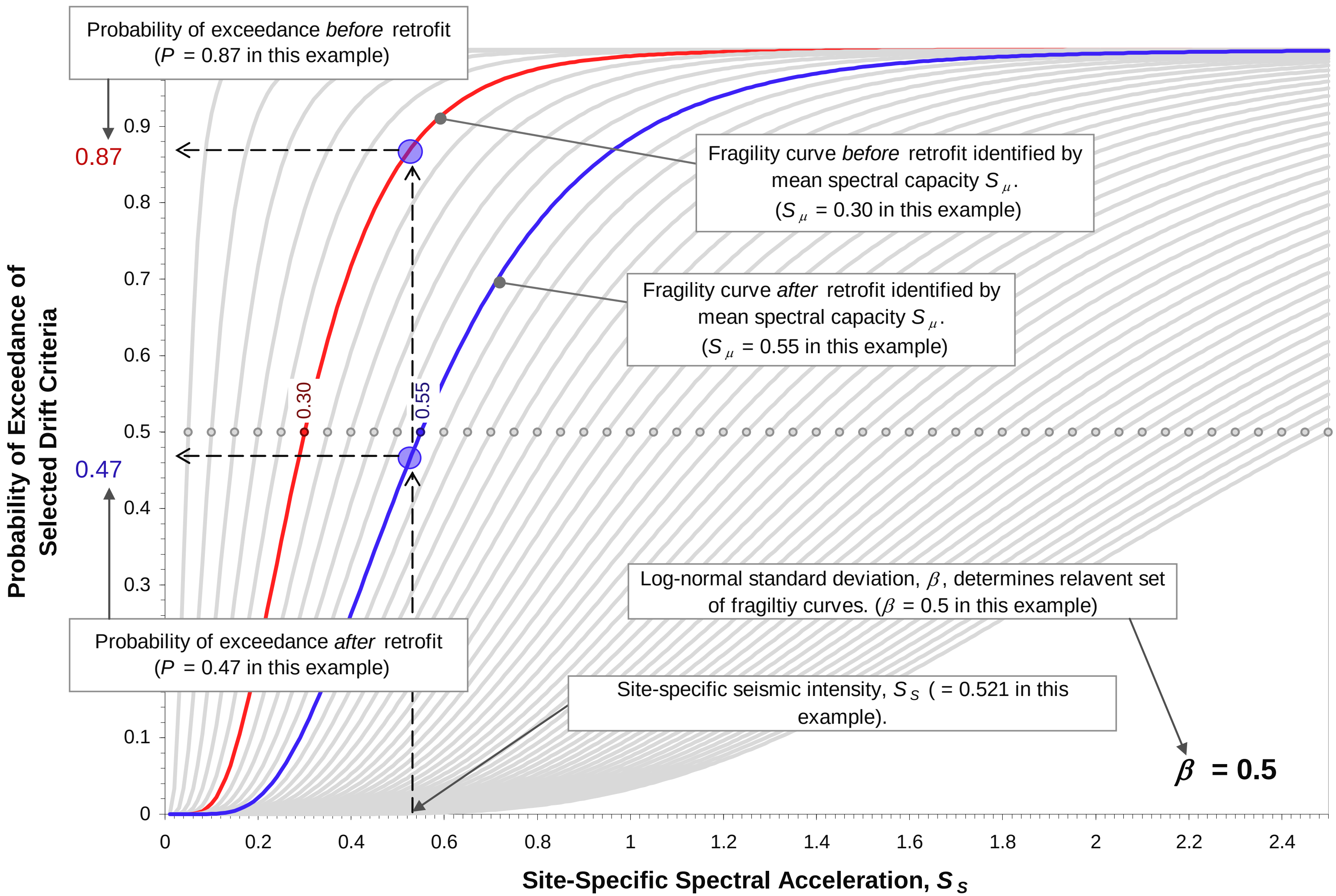
wst

weak-story tool

FEMA

Evaluation and Retrofit Guidelines for Weak-Story Wood Buildings

Probabilistic Understanding of Retrofit Benefit



Needs

More Testing of Archaic Materials

Pre –Engineered Moment Frames

Comprehensive Design & Detailing Examples