Performance-Based Seismic Design

Joe Ferzli, PE, SE

ckc
STRUCTURAL ENGINEERS

Performance-Based Seismic Design



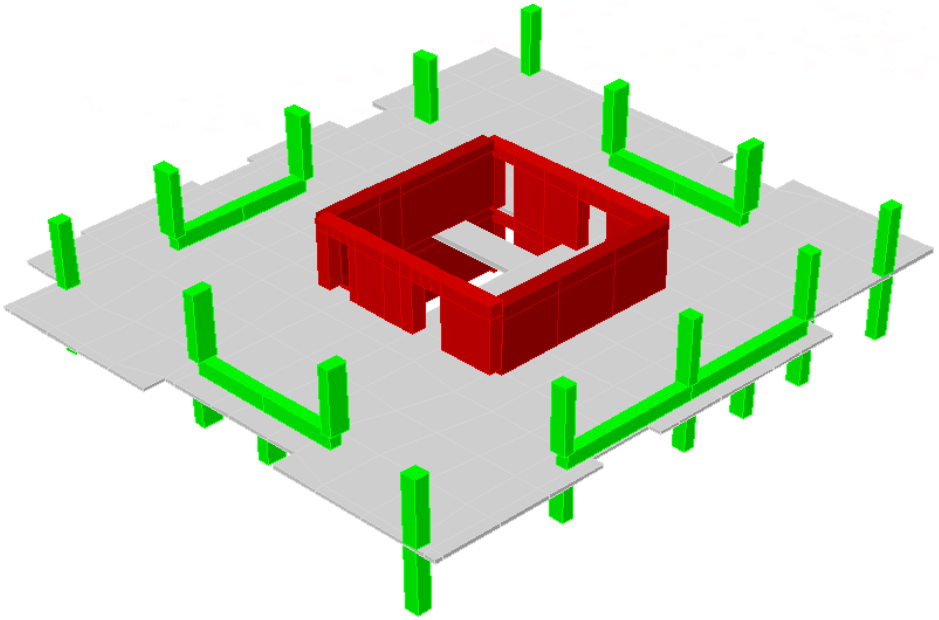





CODE VS PBSD

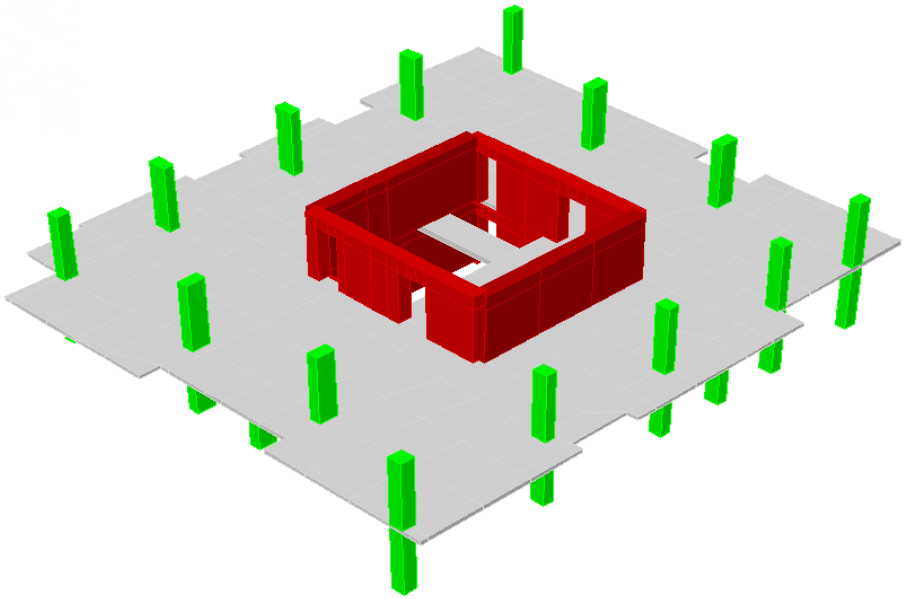
CODE

LAYOUT

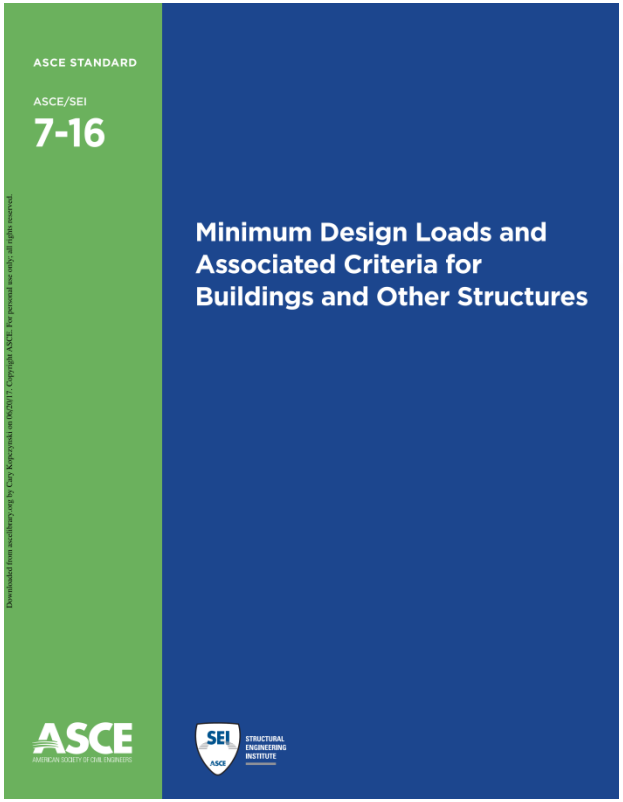


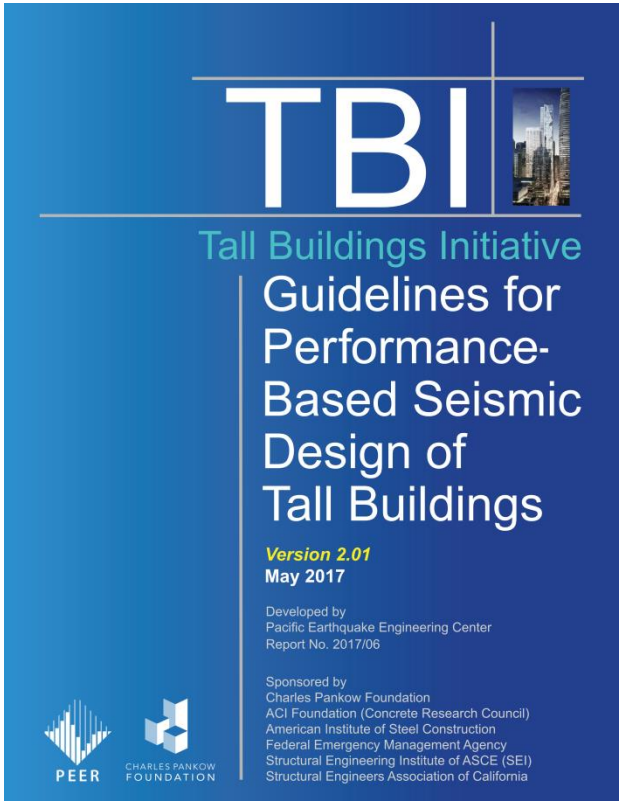
PBSD

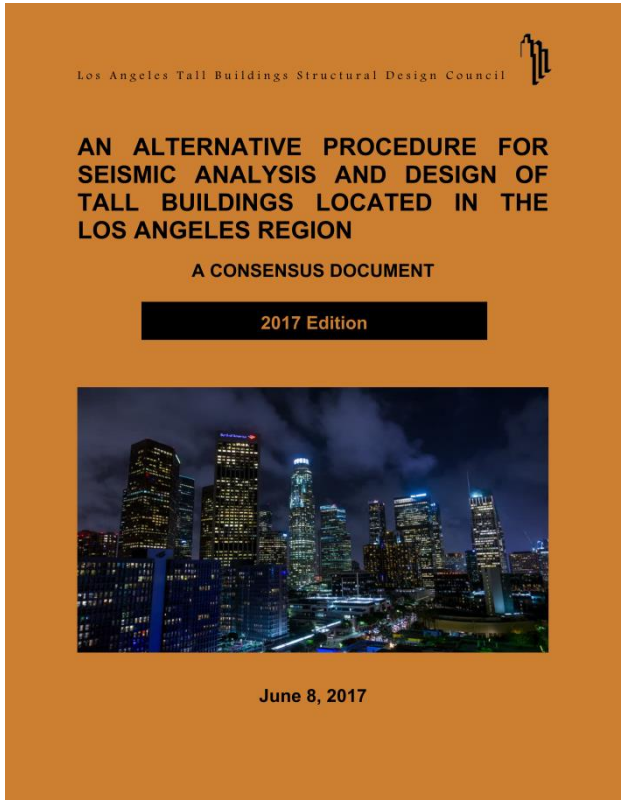
LAYOUT



GOVERNING STANDARDS

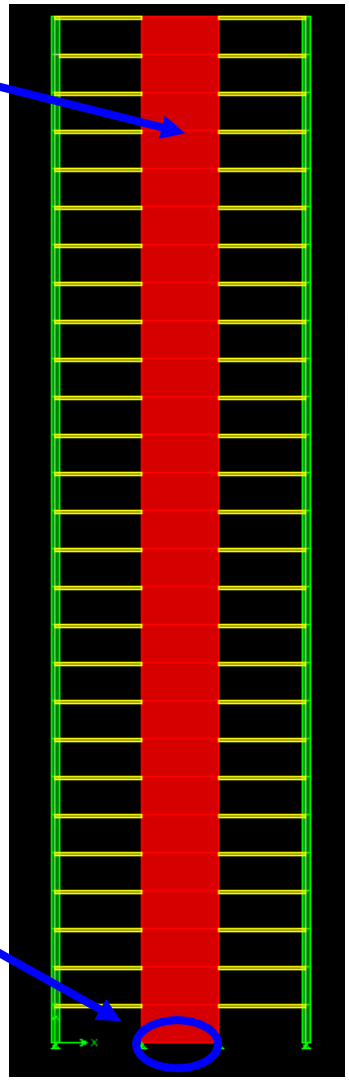


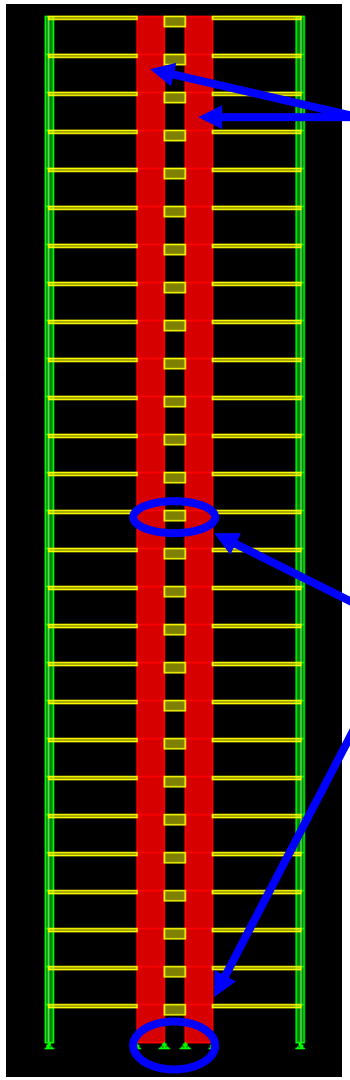




Shear Wall Behavior

Concrete core wall without openings (Cantilever wall)



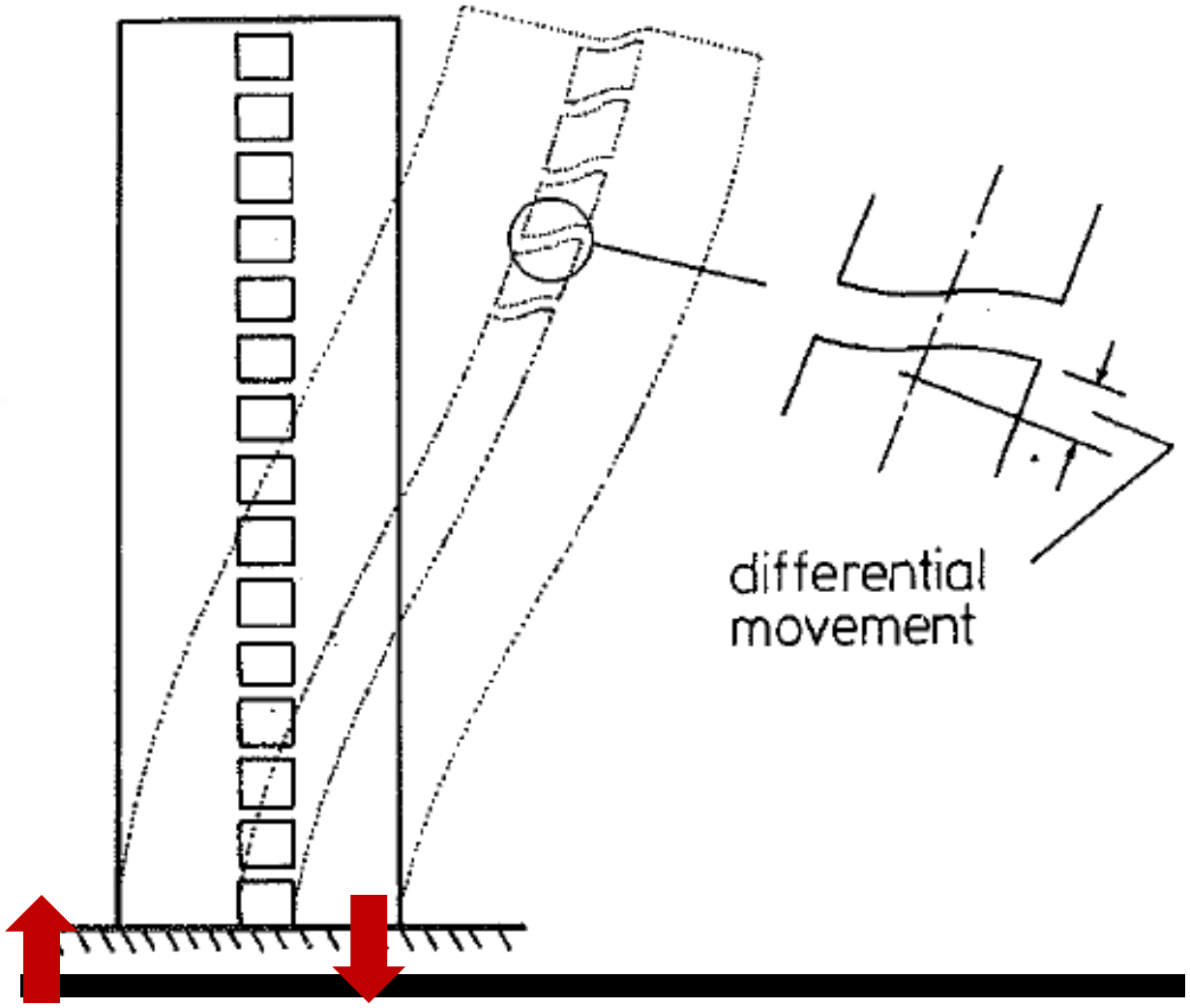


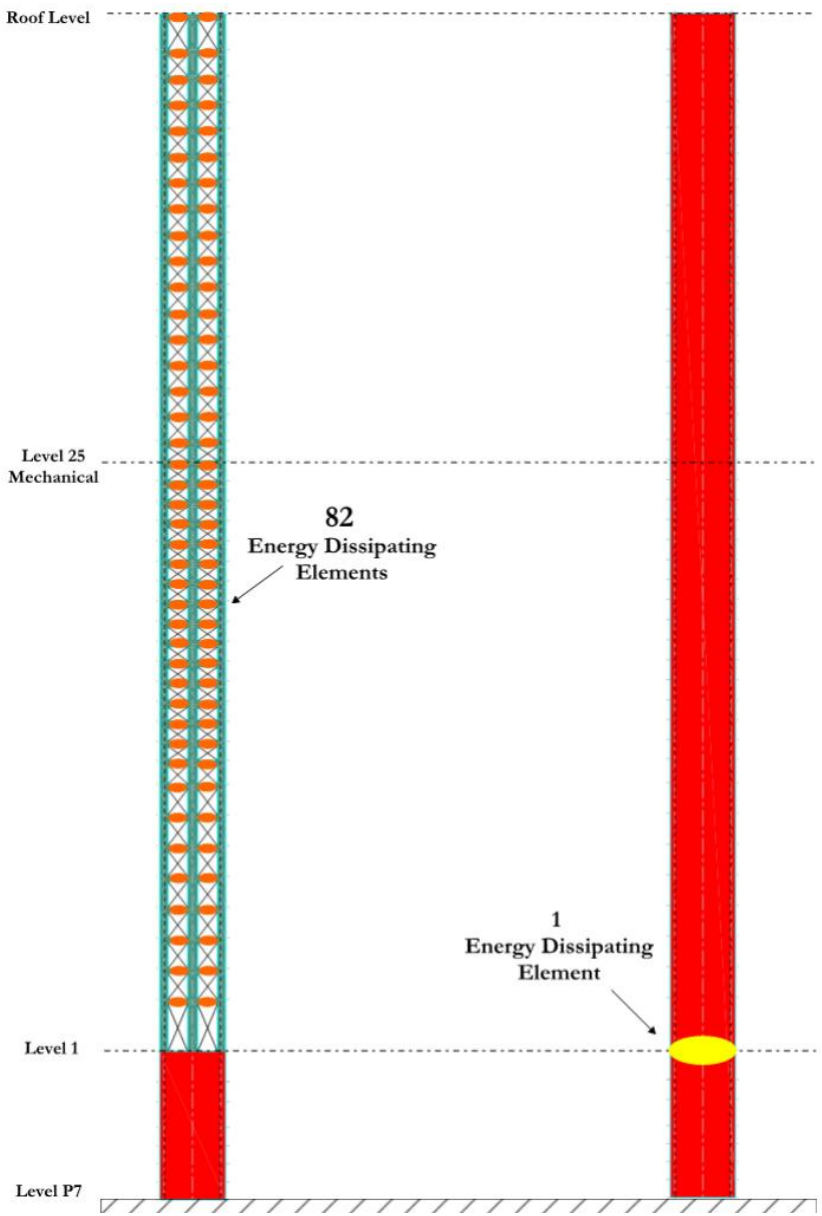
Concrete shear wall with openings (Coupled Wall)

Plastic hinge locations at coupling beams and base of wall

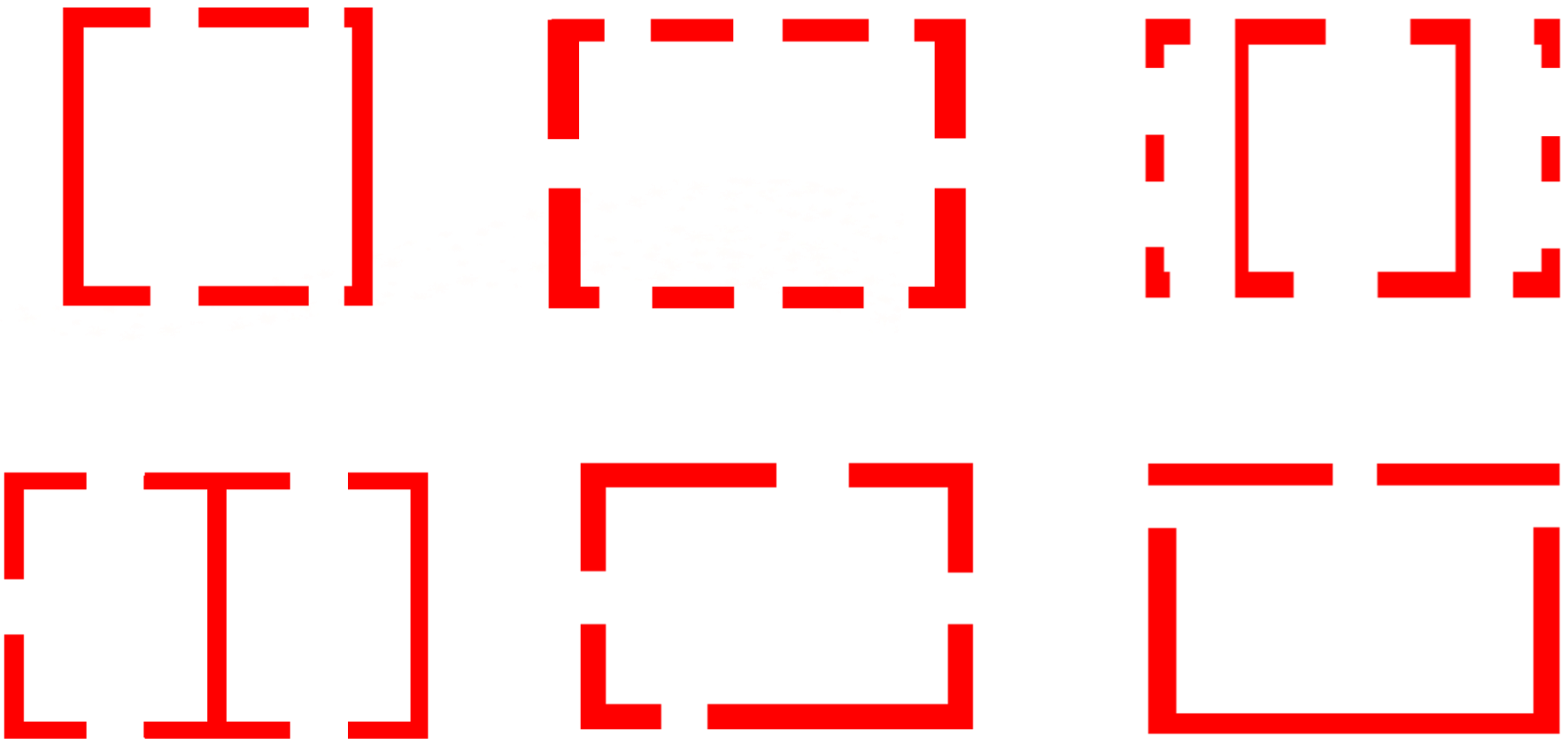
Flexural plastic hinge location, detailed for ductility

COUPLED WALLS

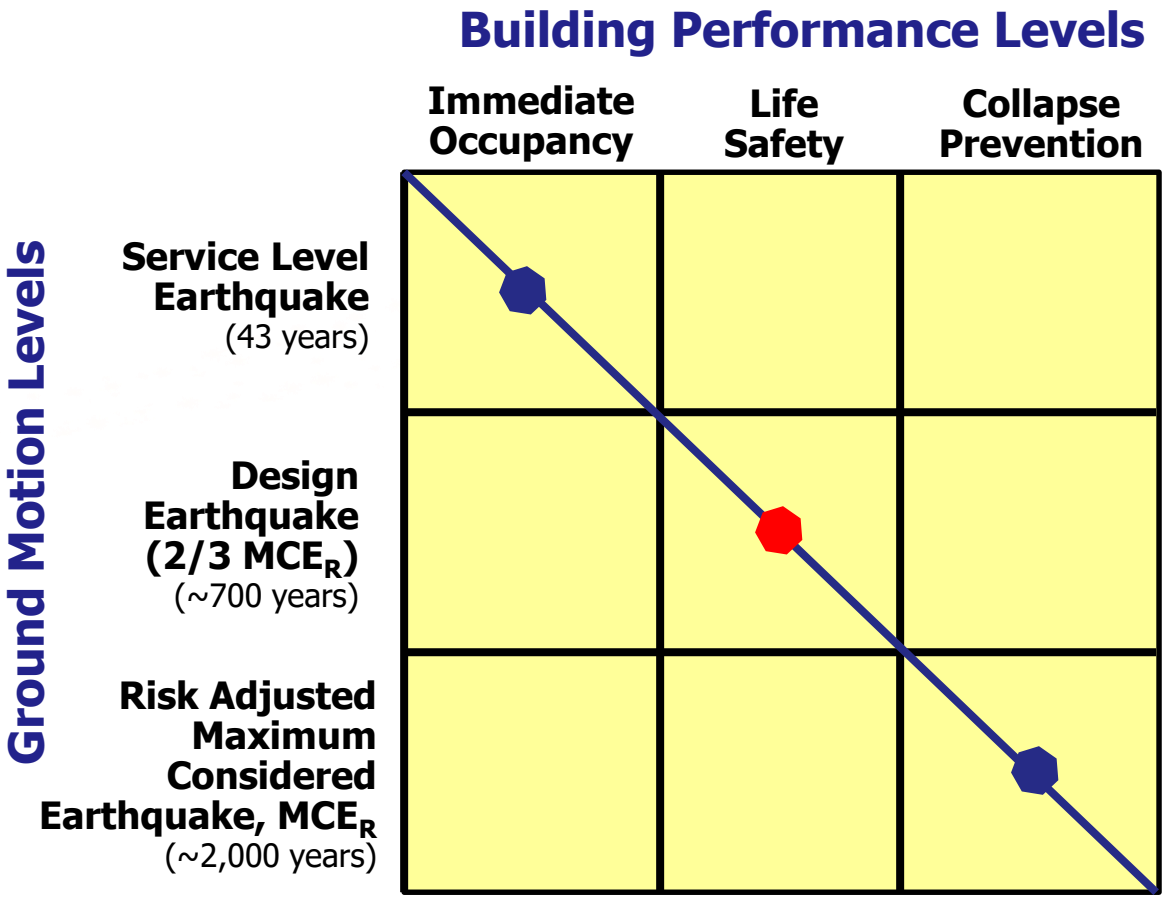


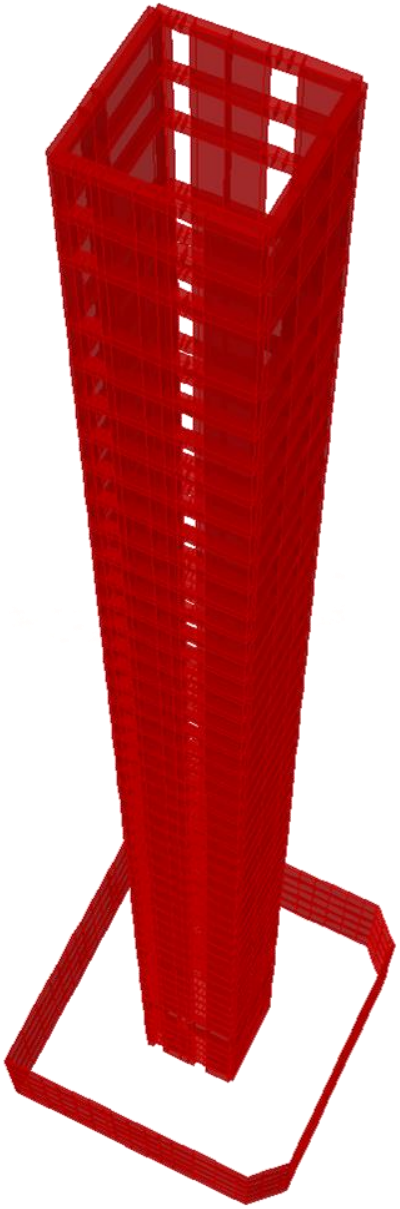

Roof Level
Level 25
Mechanical
82
Energy Dissipating
Elements
1
Energy Dissipating
Element
Level 1
Level P7

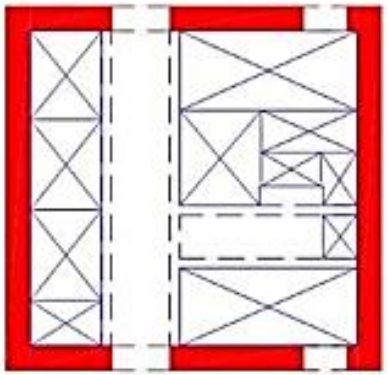
Core Wall Configurations

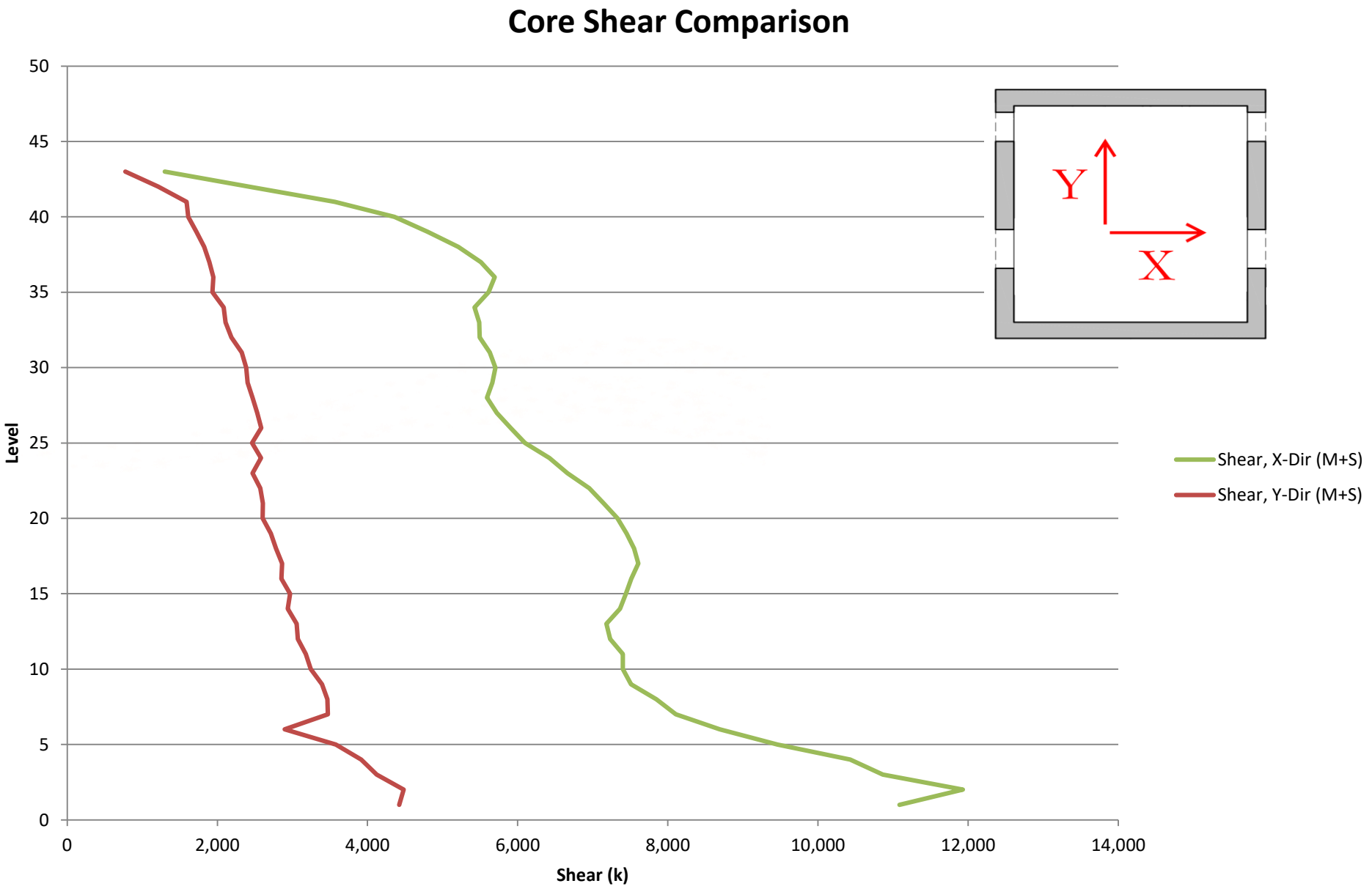


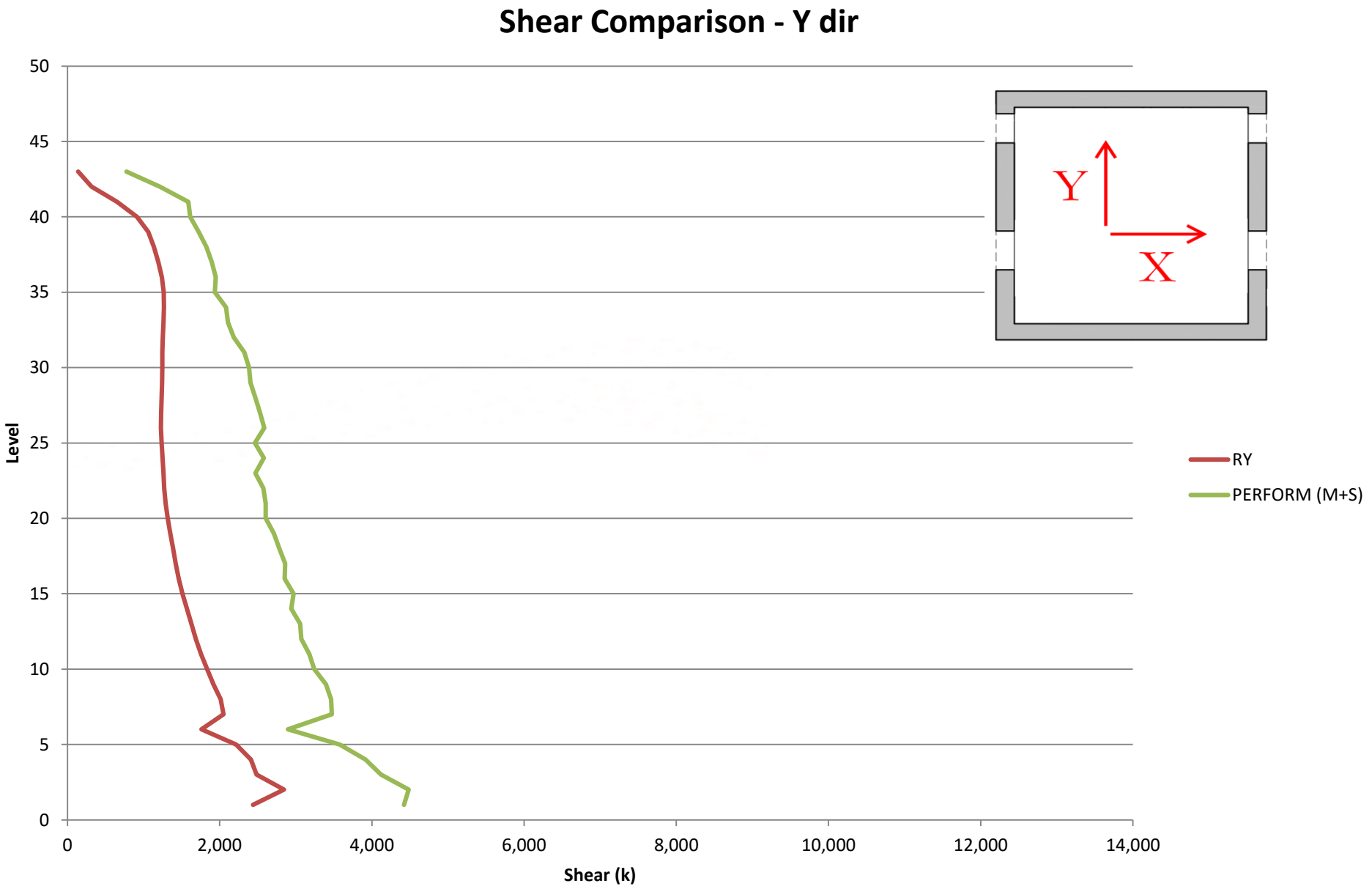
Building Seismic Performance



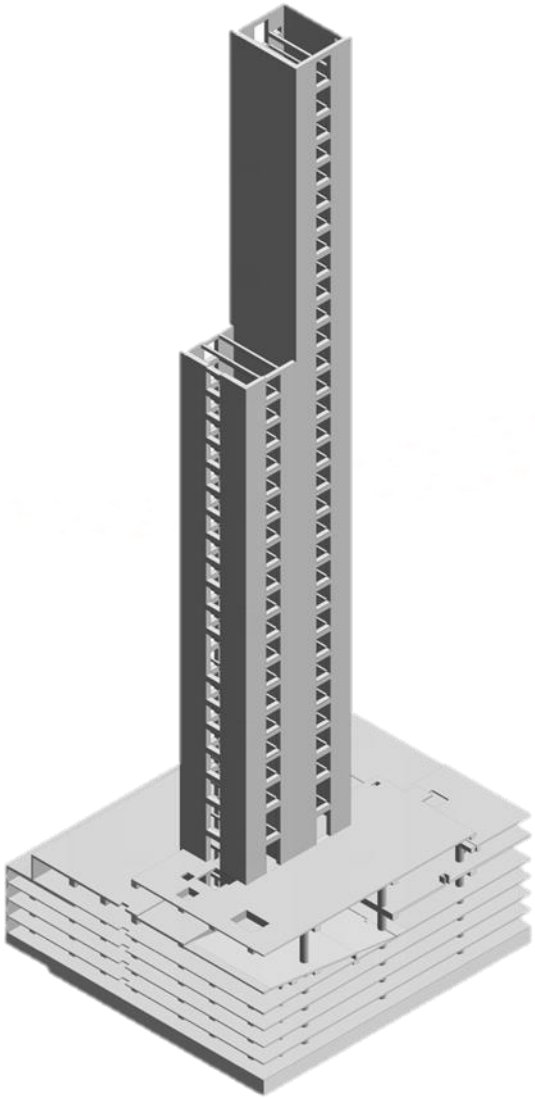




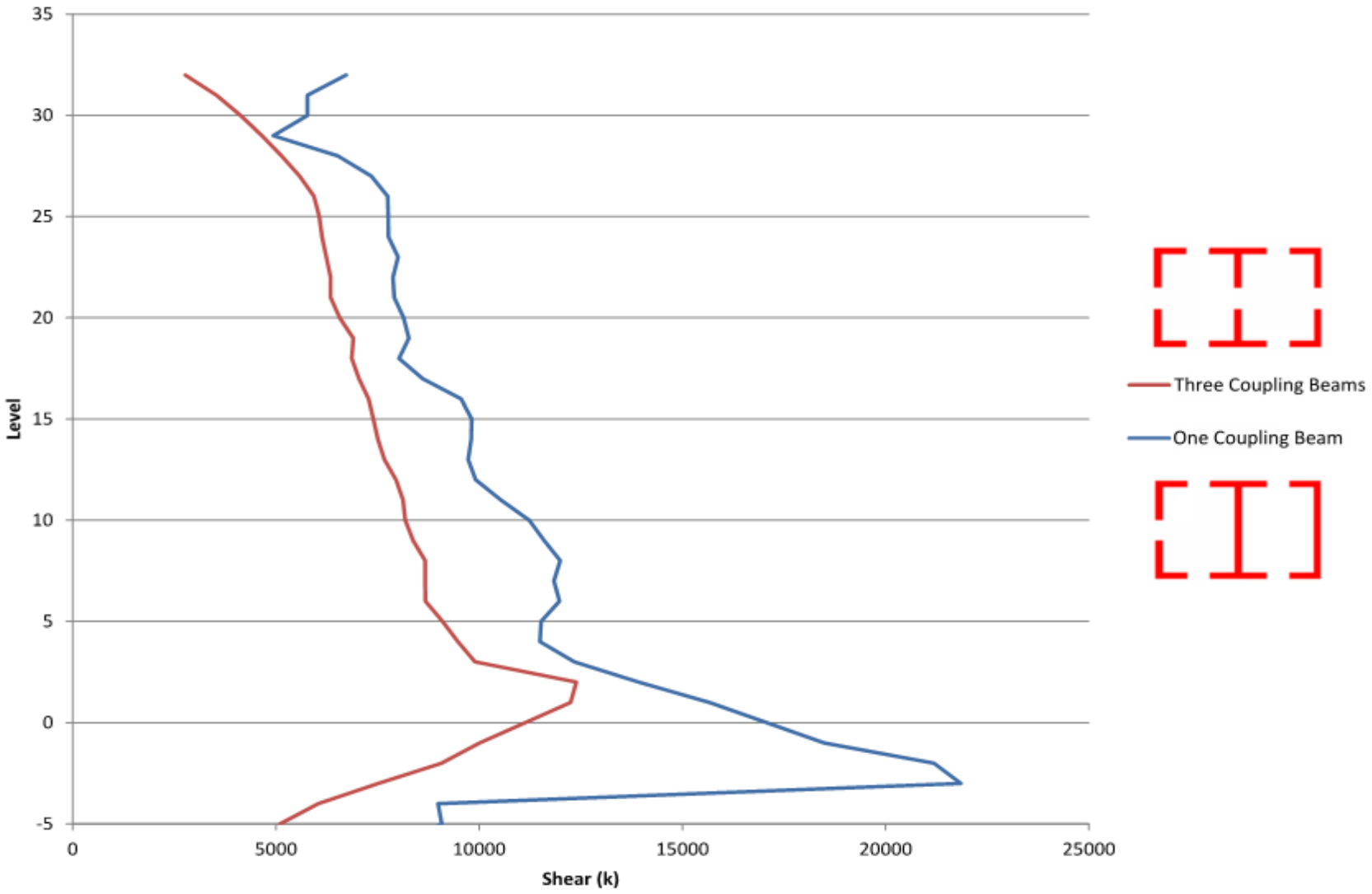

Core Shear Comparison
Level
Shear (k)
0
5
10
15
20
25
30
35
40
45
50
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Y
X
Shear, X-Dir (M+S)
Shear, Y-Dir (M+S)


Shear Comparison - Y dir
Level
Shear (k)
0
5
10
15
20
25
30
35
40
45
50
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Y
X
RY
PERFORM (M+S)

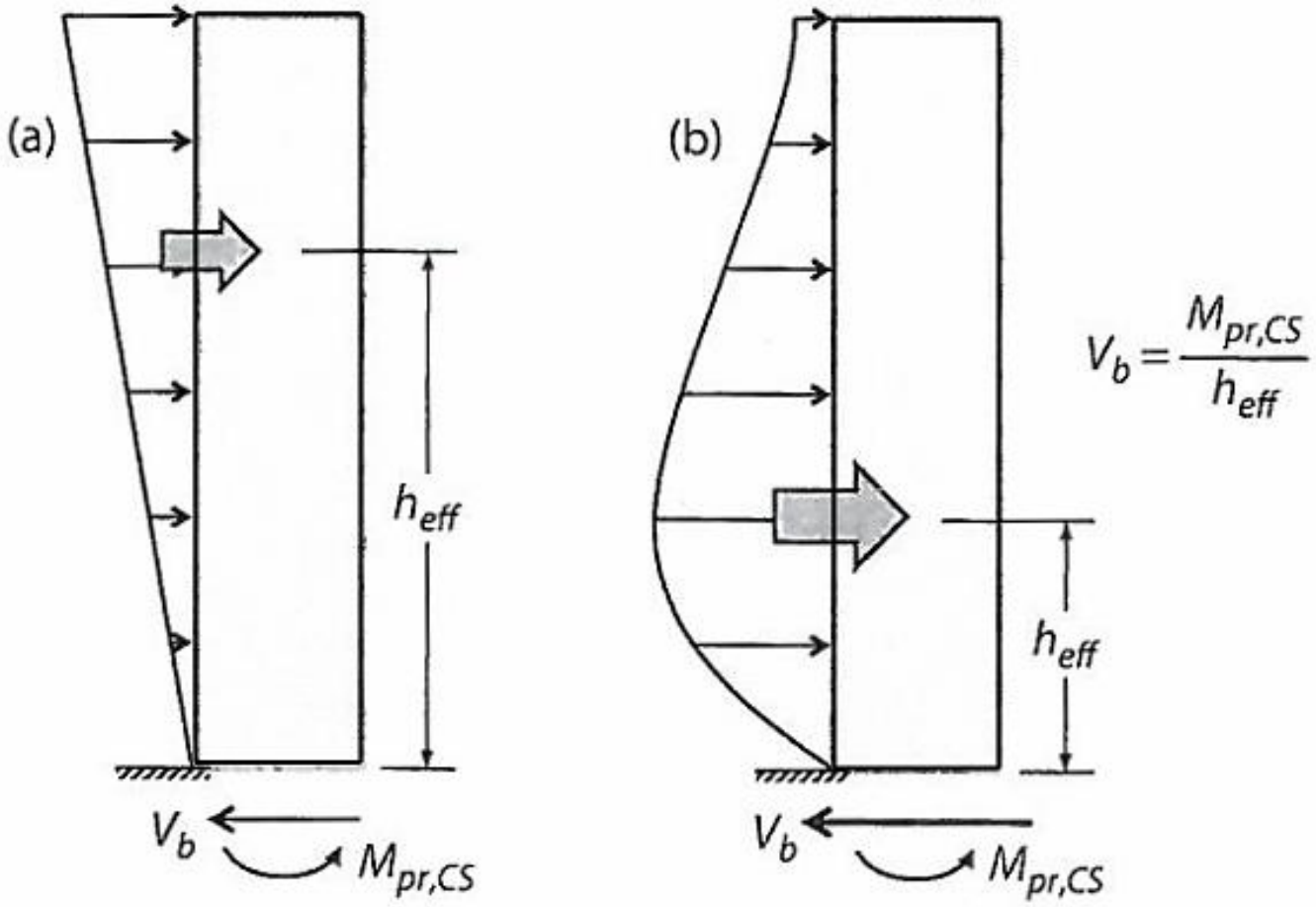
CORE GEOMETRY STUDY



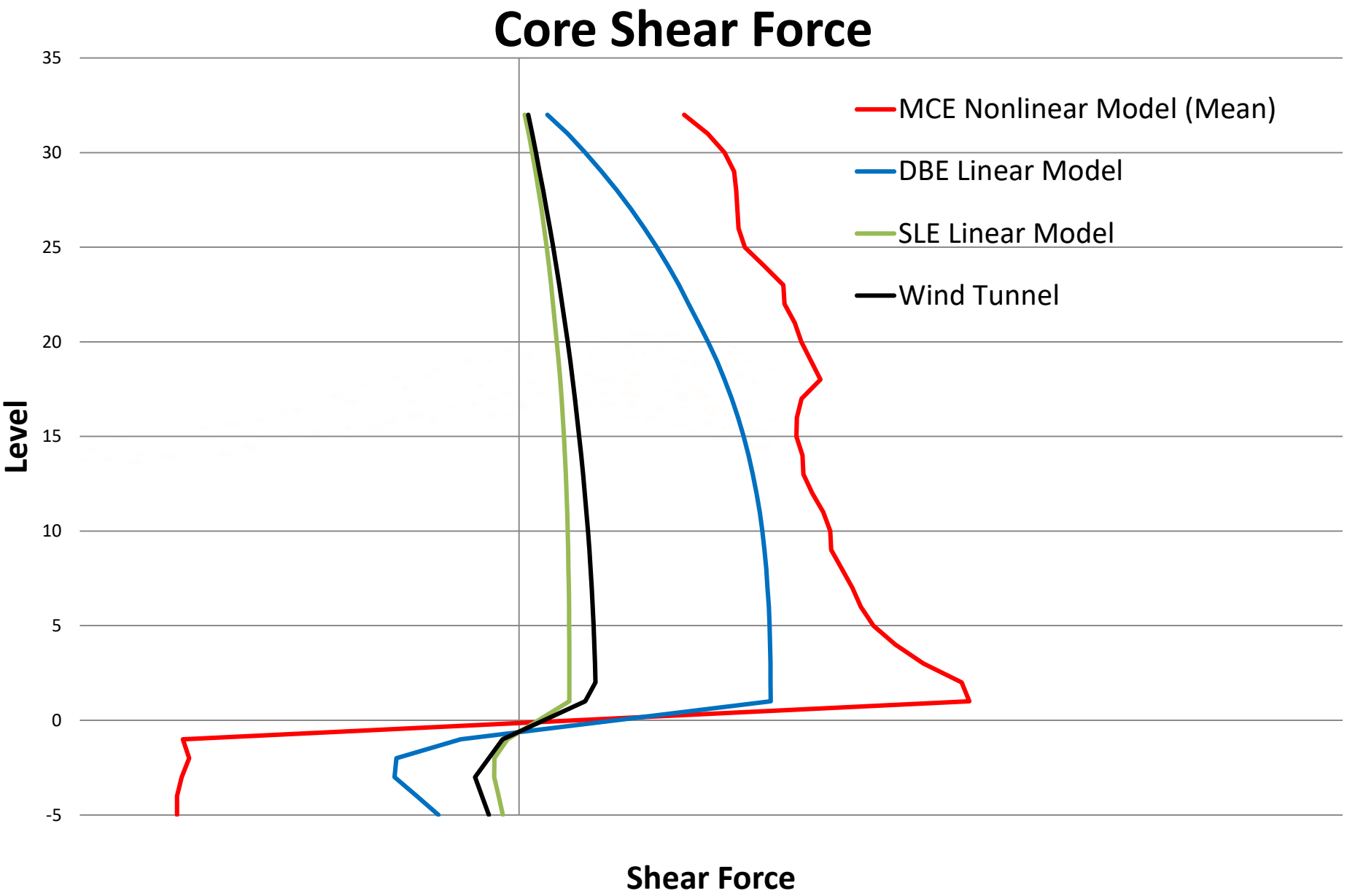
Core Shear Comparison

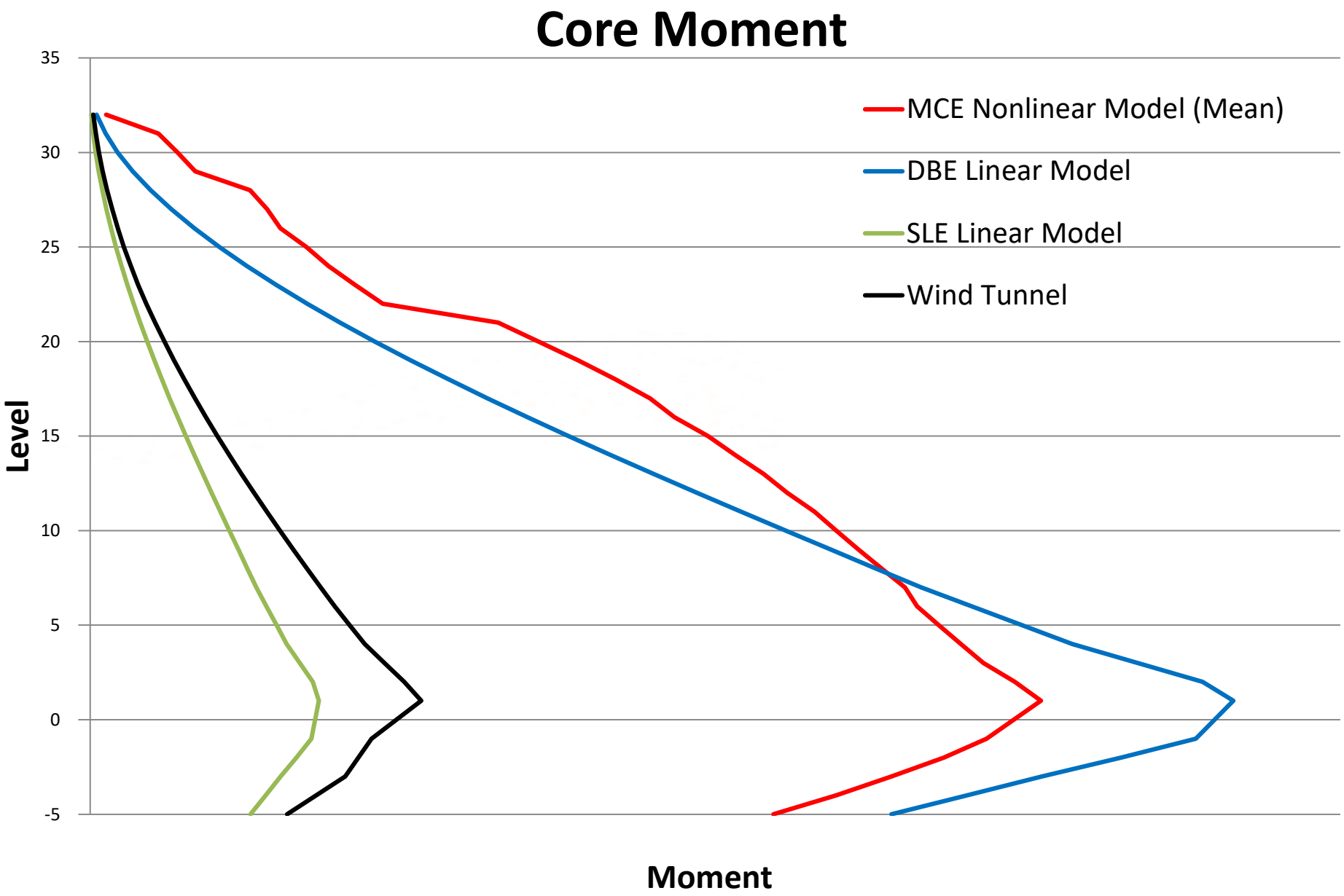


DYNAMIC AMPLIFICATIONS

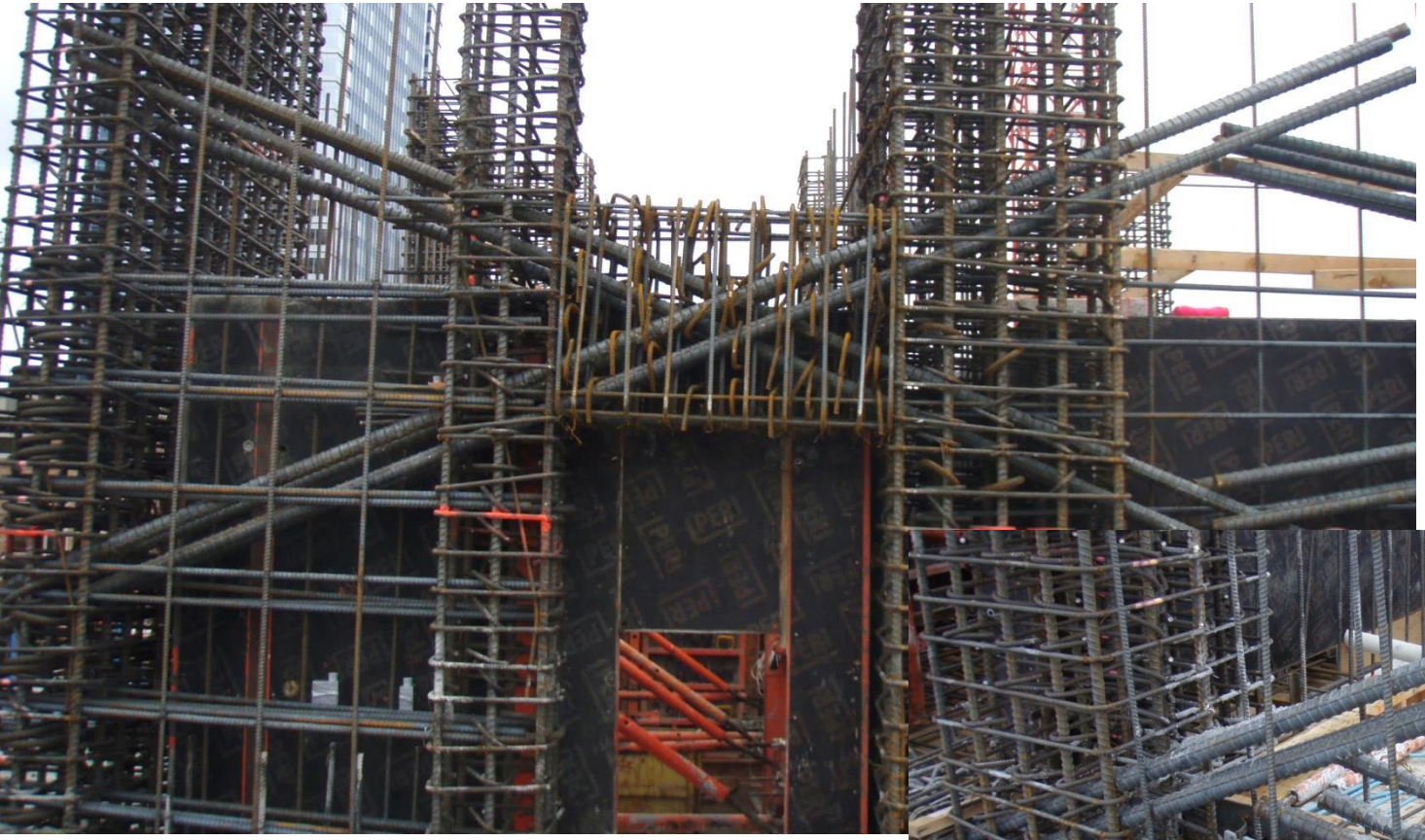


DYNAMIC AMPLIFICATIONS

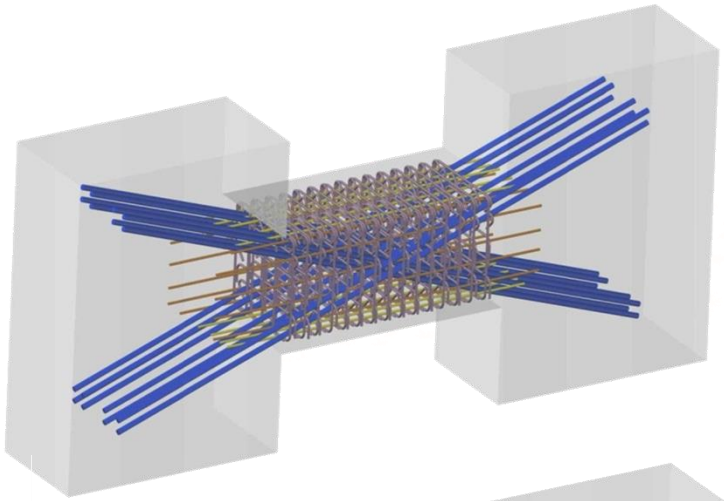

Core Shear Force
35
30
25
20
15
10
5
0
-5
Level
MCE Nonlinear Model (Mean)
DBE Linear Model
SLE Linear Model
Wind Tunnel
Shear Force


Core Moment
35
30
25
20
15
10
5
0
-5
Level
MCE Nonlinear Model (Mean)
DBE Linear Model
SLE Linear Model
Wind Tunnel
Moment

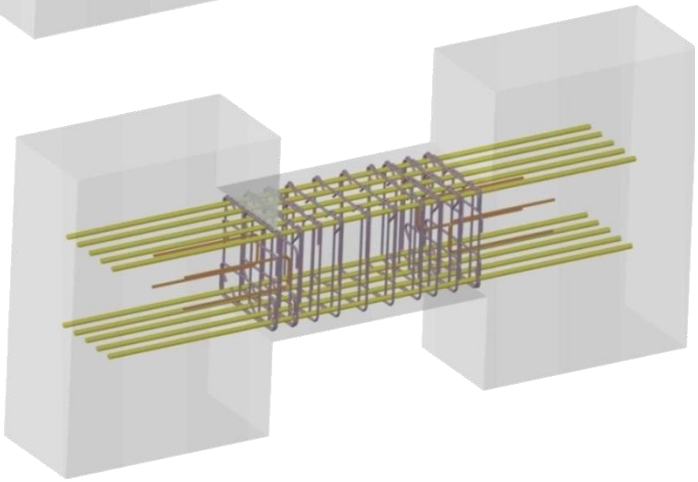
Diagonally Reinforced Coupling Beams



Diagonally Reinforced vs. SFRC Coupling Beams

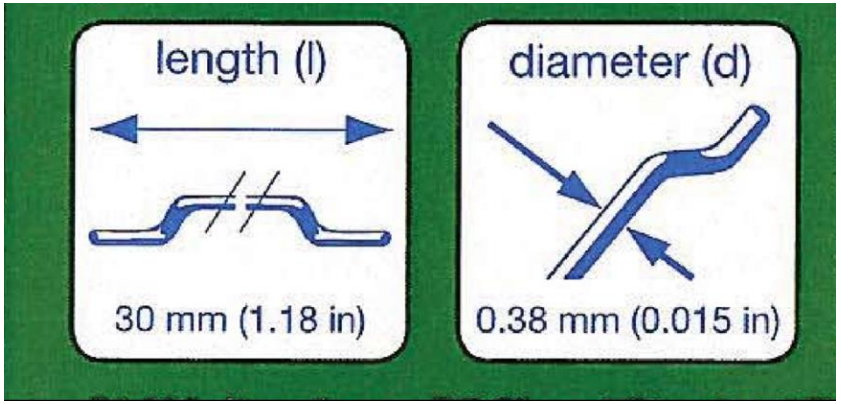


Diagonally Reinforced Concrete Coupling Beam



Steel Fiber Reinforced Concrete (SFRC) Coupling Beam

Bekaert Dramix© Steel Fibers



Diameter: 0.015"

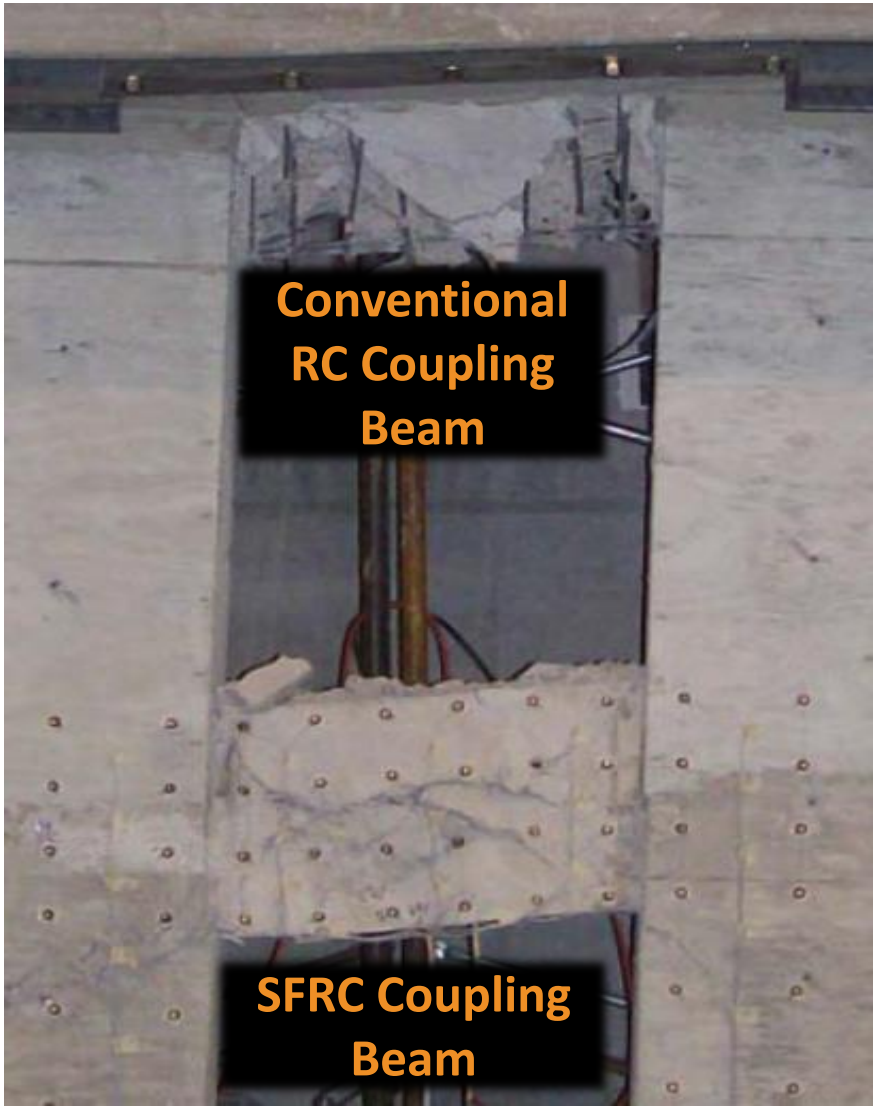
Length: 1.18"

Strength: 445 ksi

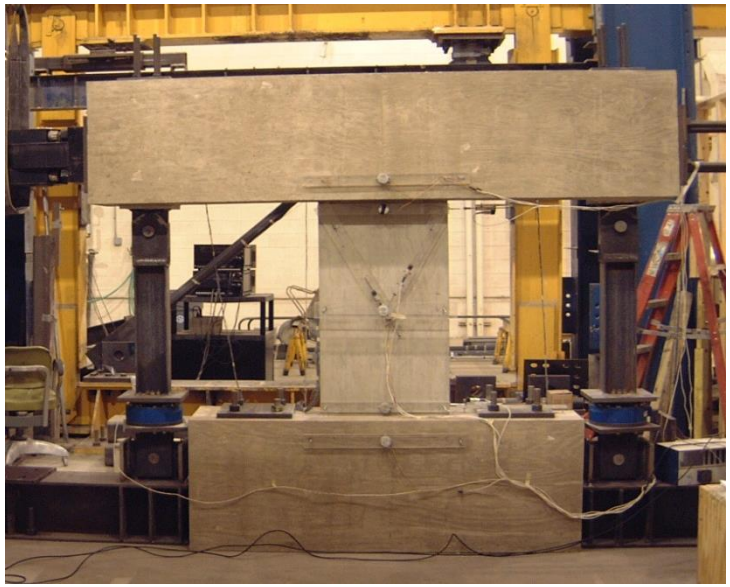
Material: ASTM A820

Dosage: 1.5% by volume
= 200 #/yd³

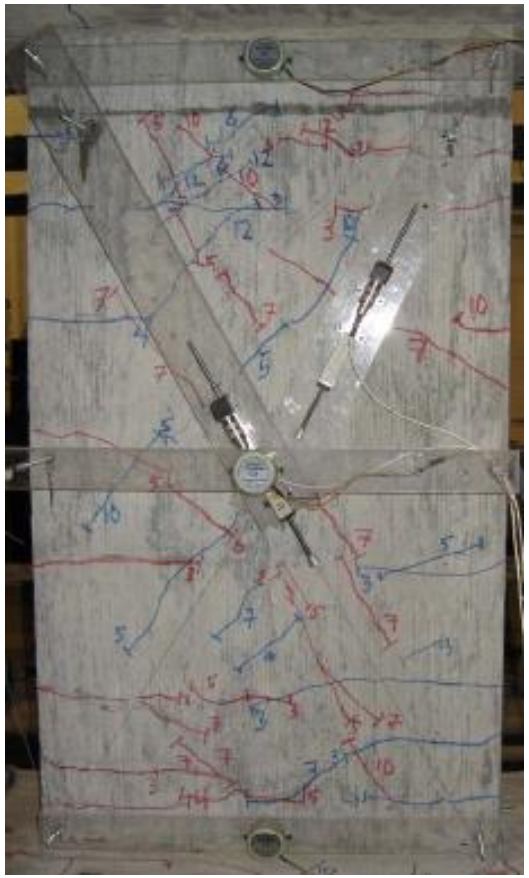
Coupled Wall Test



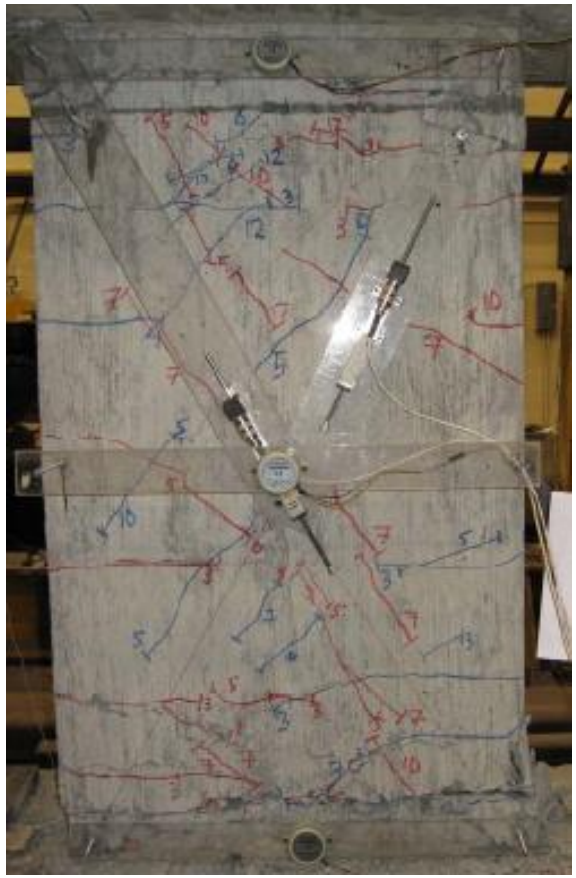
SFRC Coupling Beam Testing



TESTED WITH
ASPECT RATIOS
[1.75 2.75 3.3]



3% Drift



5% Drift

SFRC Coupling Beams

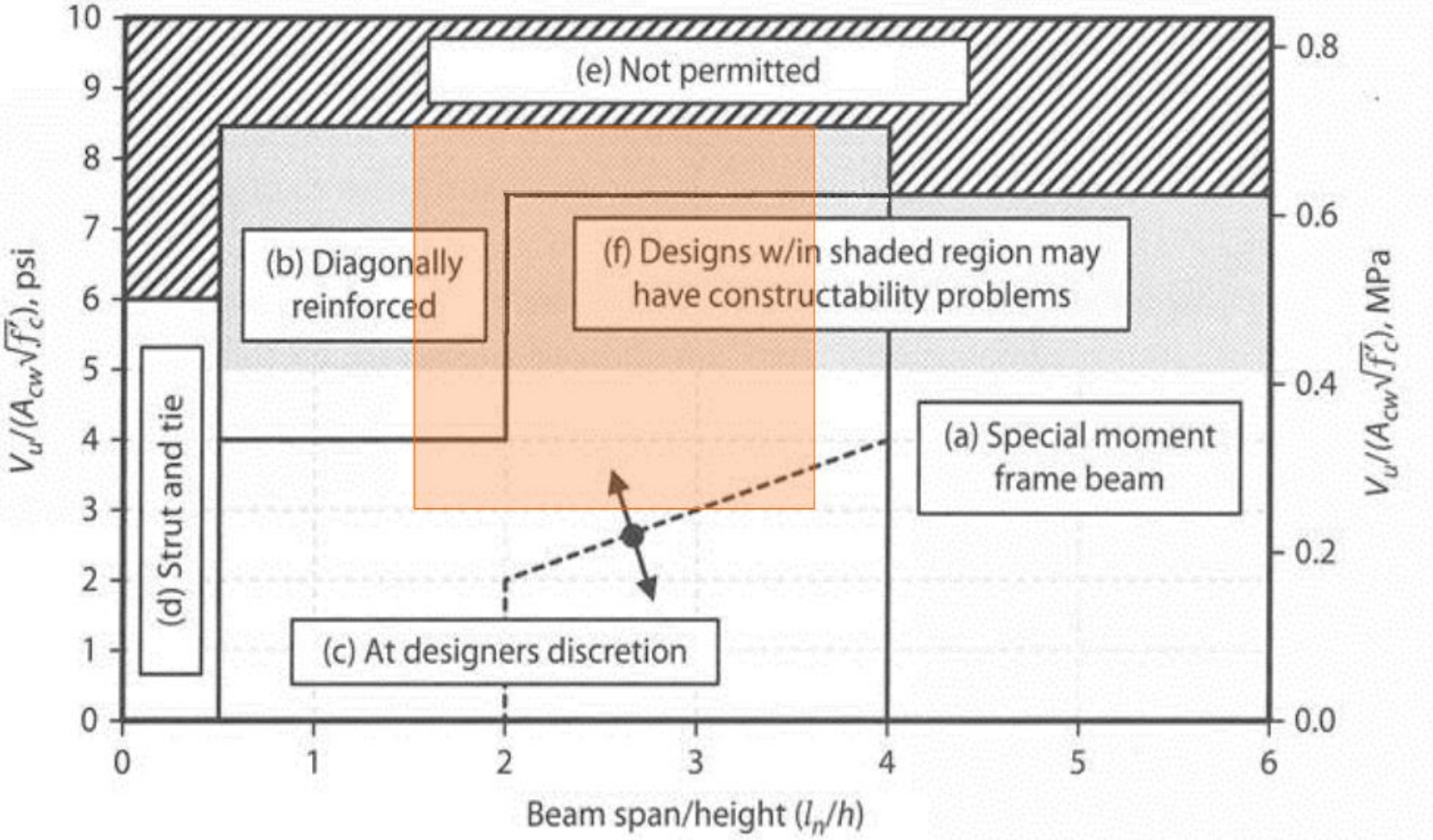


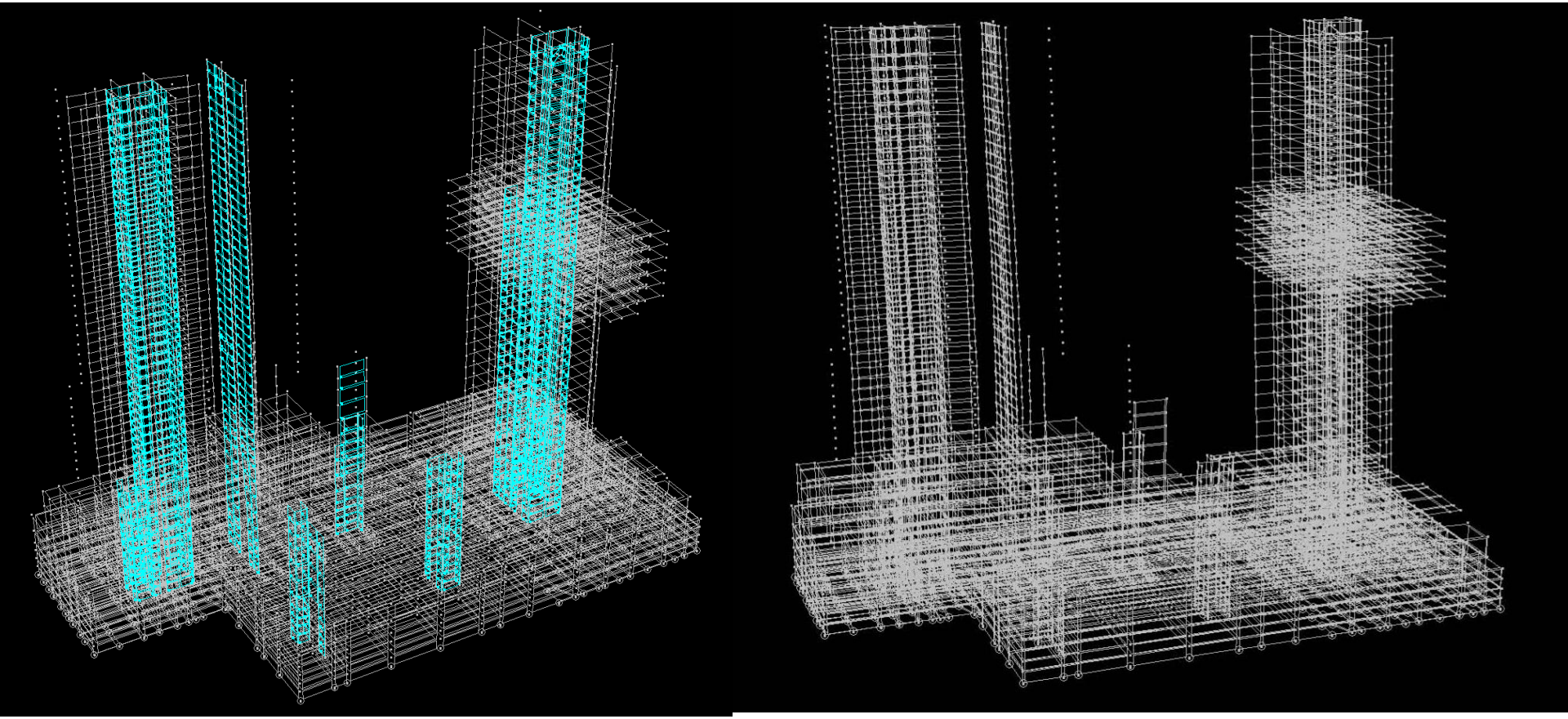
Figure 13.45 Coupling beam design space.

The Concrete Convention and Exposition

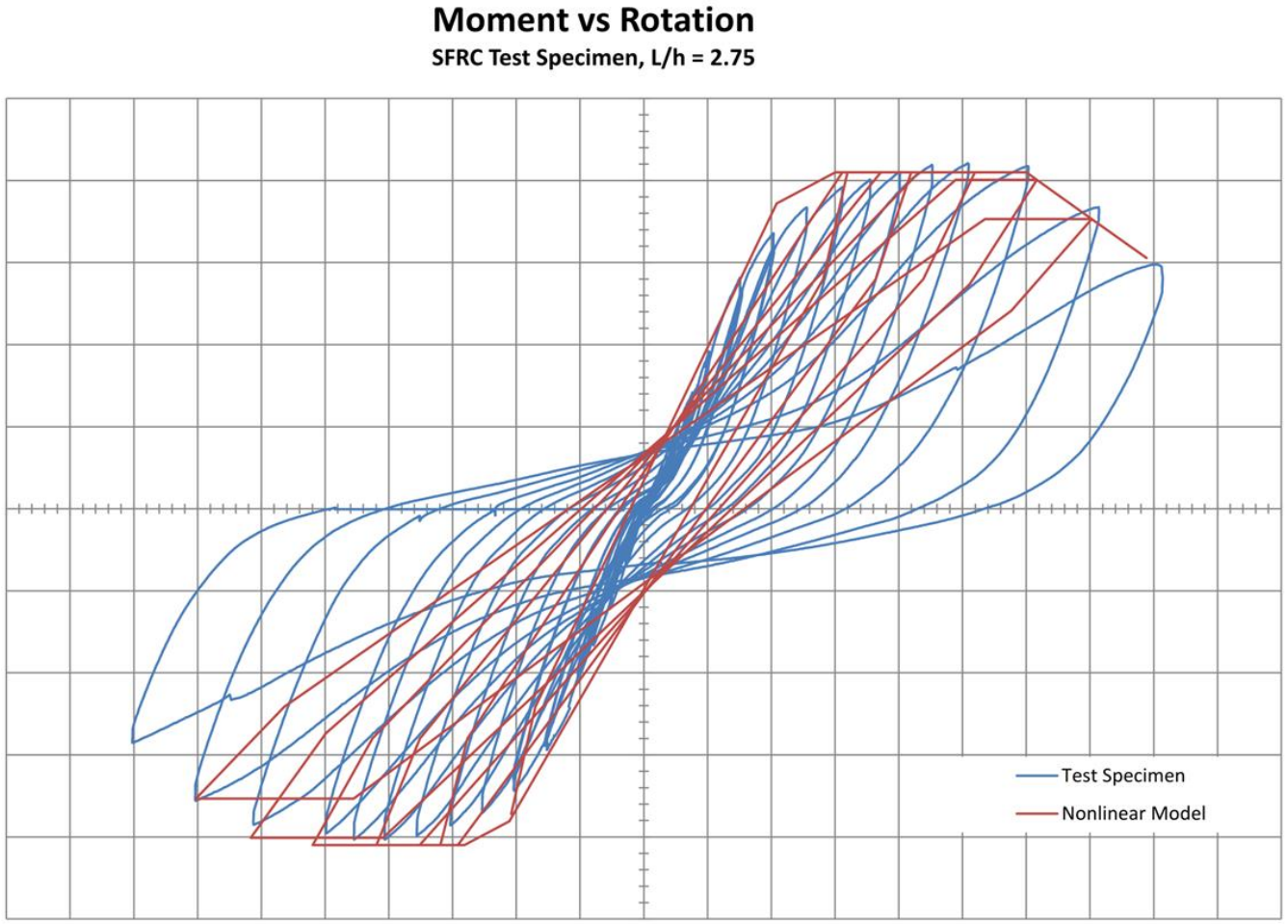
LINCOLN SQUARE EXP

BELLEVUE

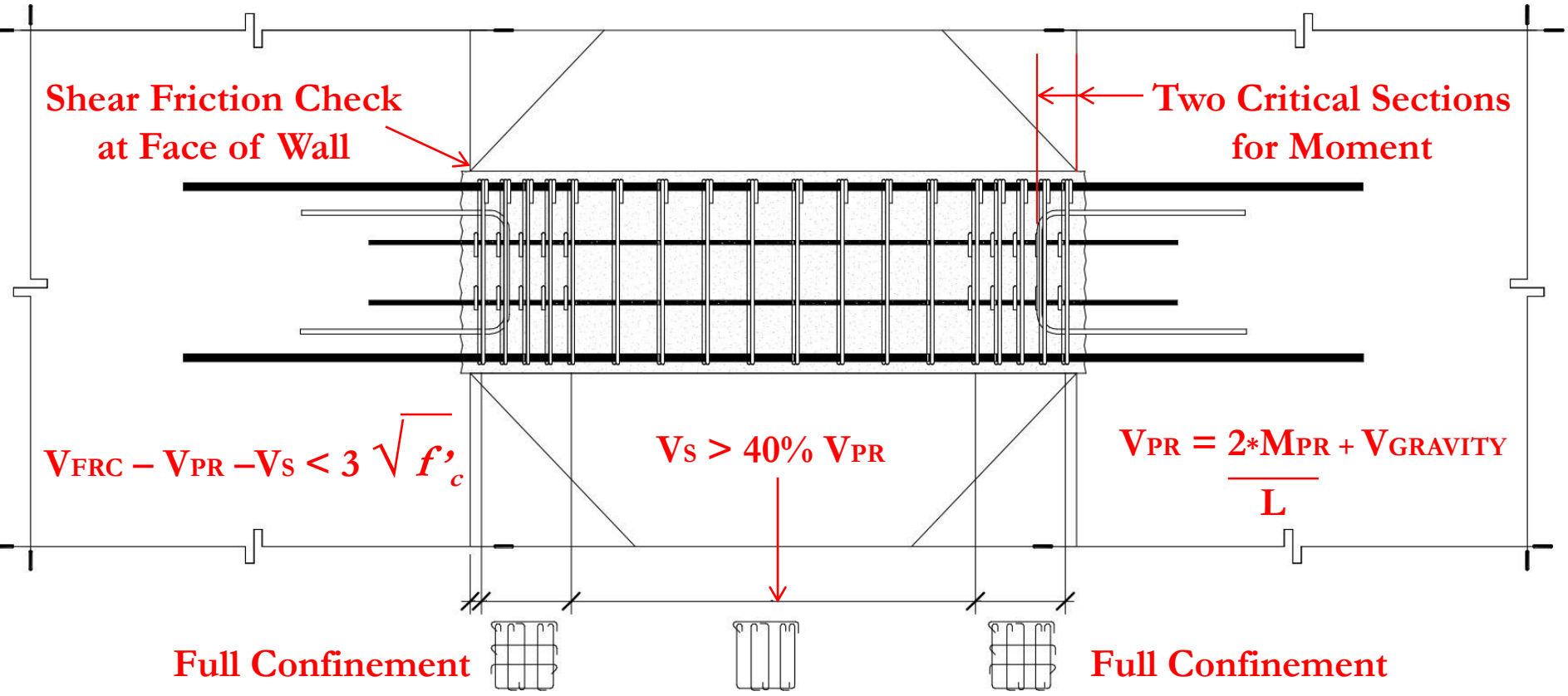
3D PERFORM MODEL



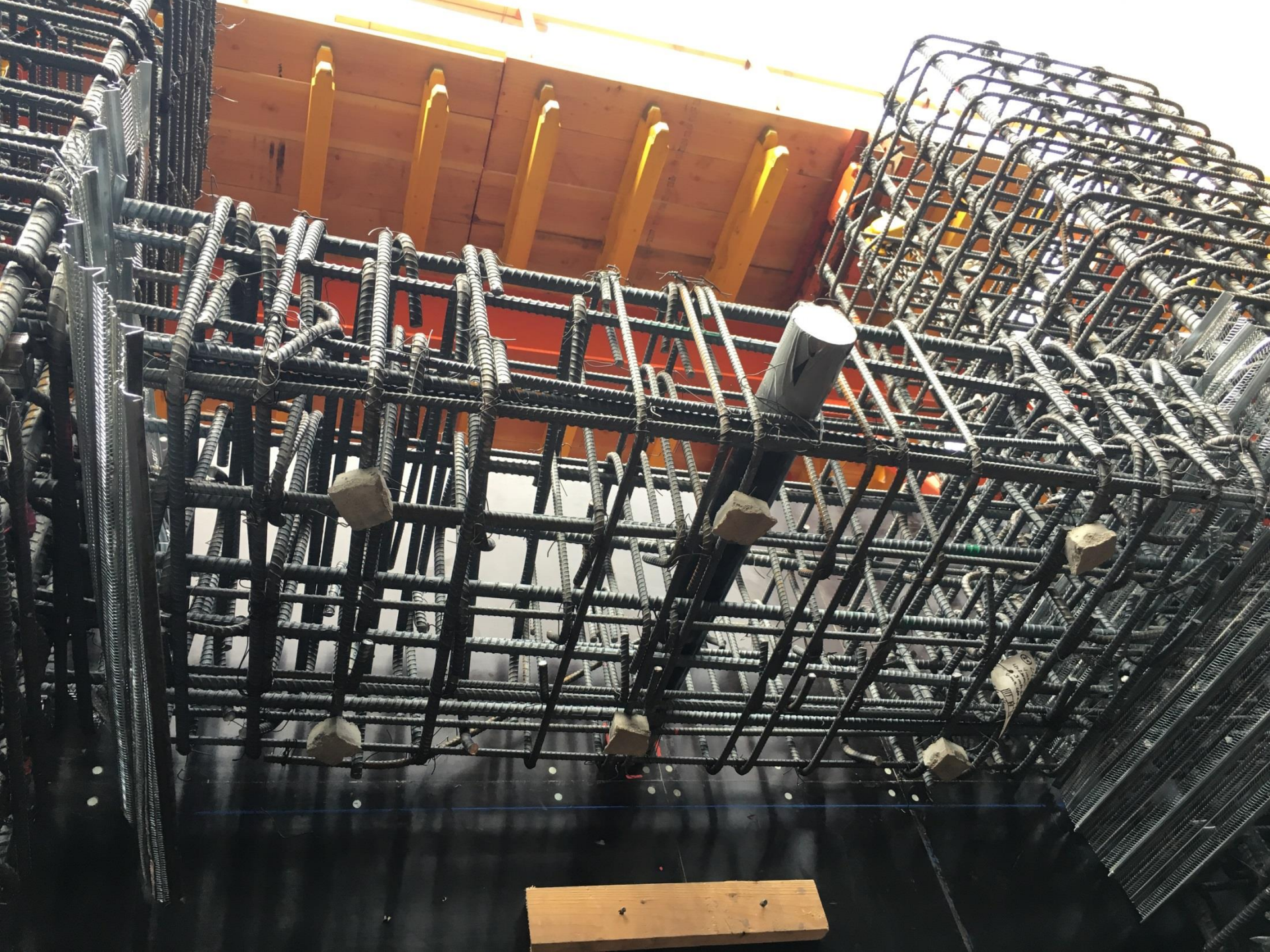
Analytical Model Calibration



DESIGN PROCEDURE OF SFRC BEAM



- Full coupling beam section is active for resisting shear (reinforcement steel and concrete)
- Shear steel reinforcement shall be greater then 40% of design ***VPR***
- The remainder of shear attributed to SFRC $\leq 3\sqrt{f'_c}$



SFRC Coupling Beams Application

Performance-Based Seismic Design

Joe Ferzli, PE, SE

ckc
STRUCTURAL ENGINEERS