Rocking Walls with Lead Extrusion Dampers
Protect Formerly Homeless Seniors from Earthquake Risks

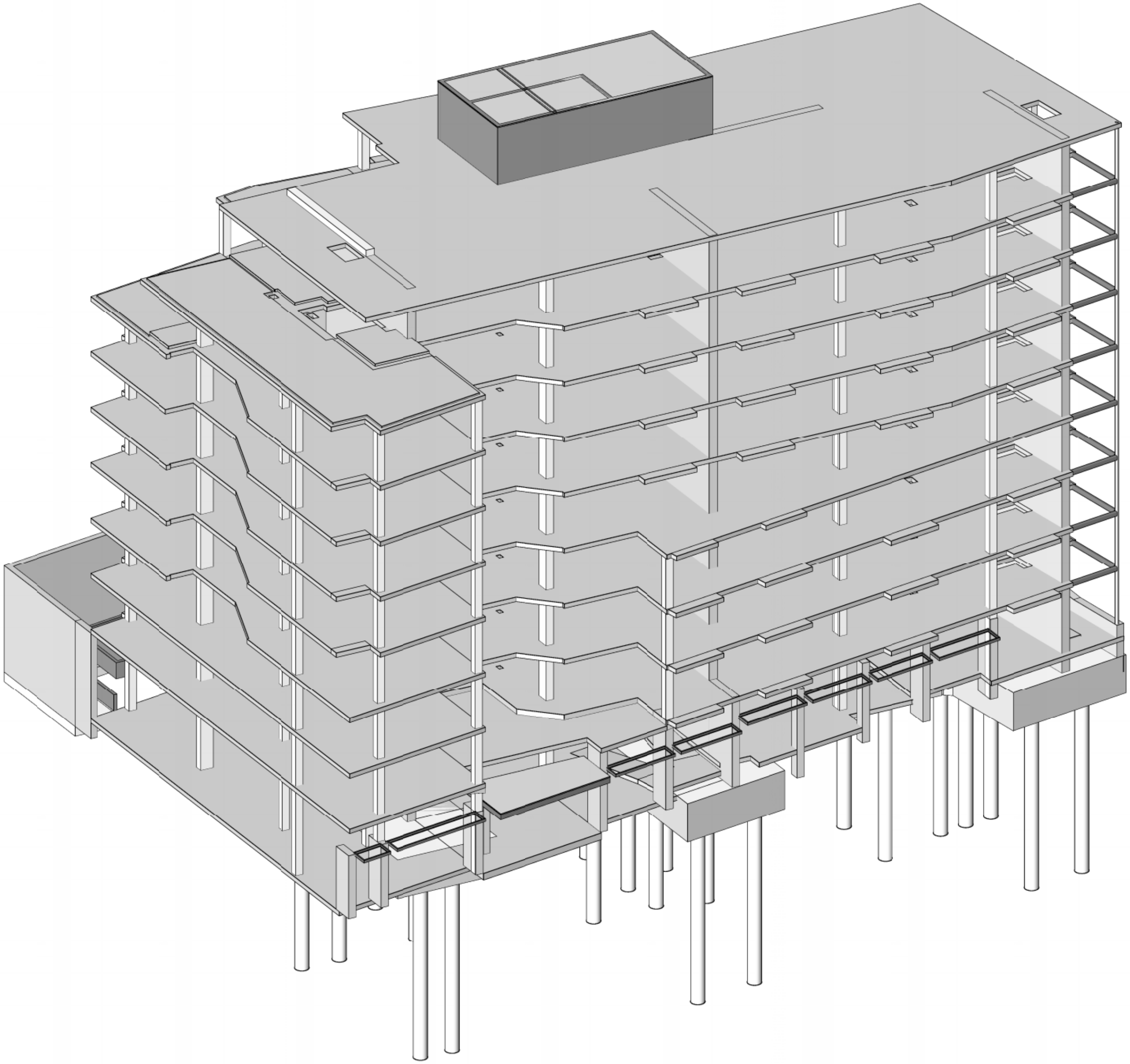
100% Affordable Senior Housing

20% of Units for Formerly Homeless

No Money

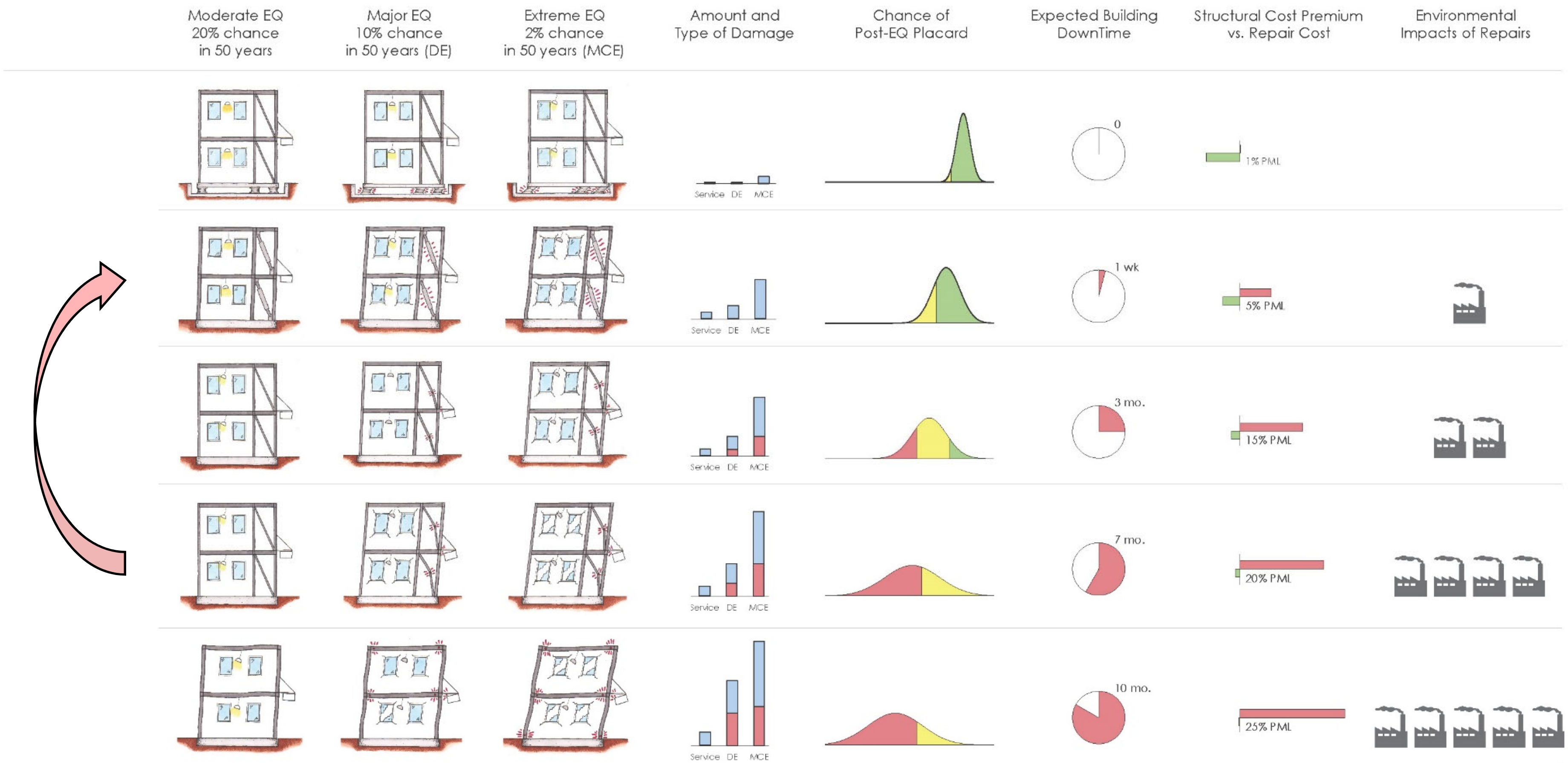
for

Improved Performance



UNDERSTANDING PERFORMANCE-BASED DESIGN

Information for Smart Design Decisions



Earthquake damage for code compliant buildings varies depending upon the level of shaking experienced and the characteristics of the building's structural system.

Damage to non-structural components, which can be more costly and disruptive than damage to the structure, can be measured and managed.

The odds of getting a green tag (safe), yellow tag (restricted), or red tag (unsafe) vary based on design choices.

Design choices affect the amount of time required before a building can be occupied after an earthquake.

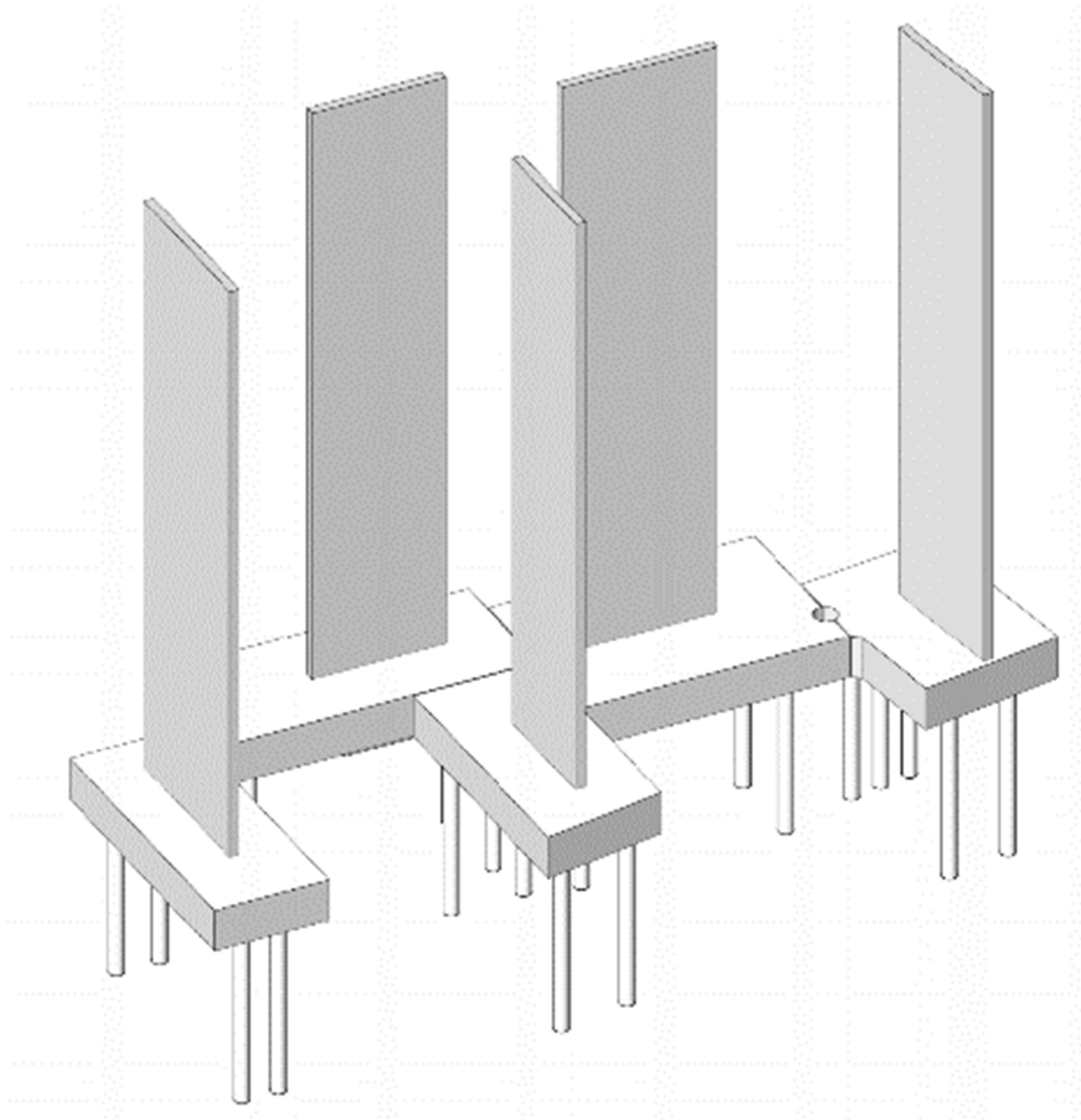
The red bar respresents PML (probable maximum loss). It is a measure of the repair cost as a percentage of building replacement cost.

The green bar represents the relative structural investment cost for an enhanced seismic performance.

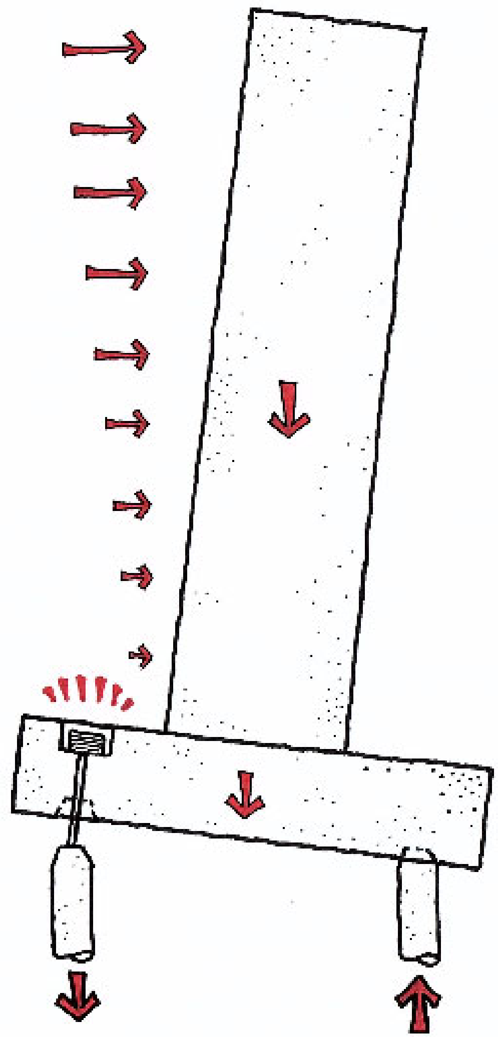
The materials and work required for post-earthquake repair have environmental consequences that can be measured.

Design Decisions Affect How Earthquakes Impact New Code-Compliant Buildings

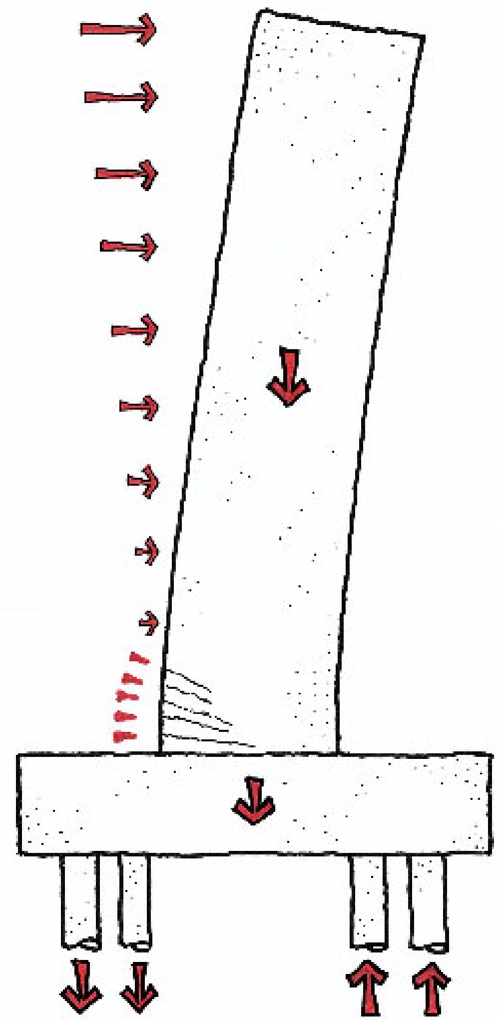
The FEMA P-58 methodology can help inform decisions by calculating expected dollar losses, repair time, chances of receiving an unsafe placard, casualties, environmental impacts, and the uncertainty of each. See www.atcouncil.org/P58 for more information.

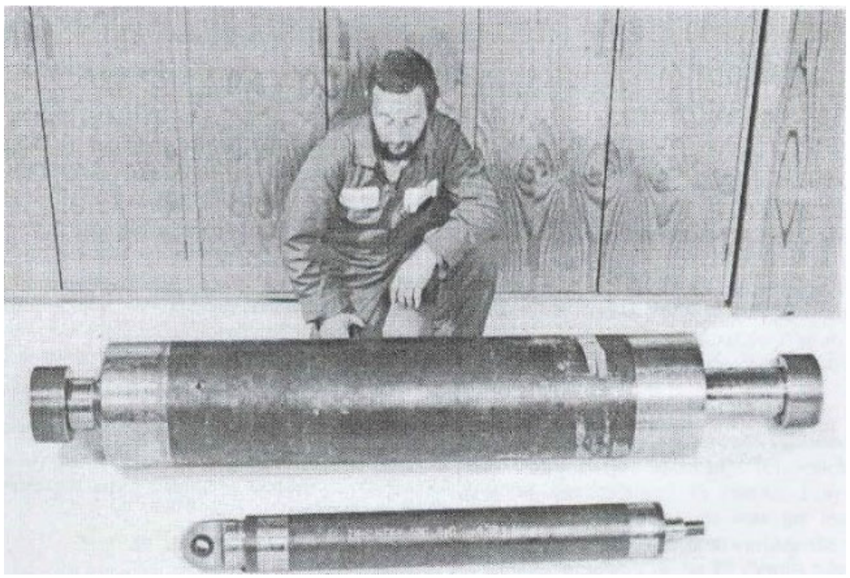


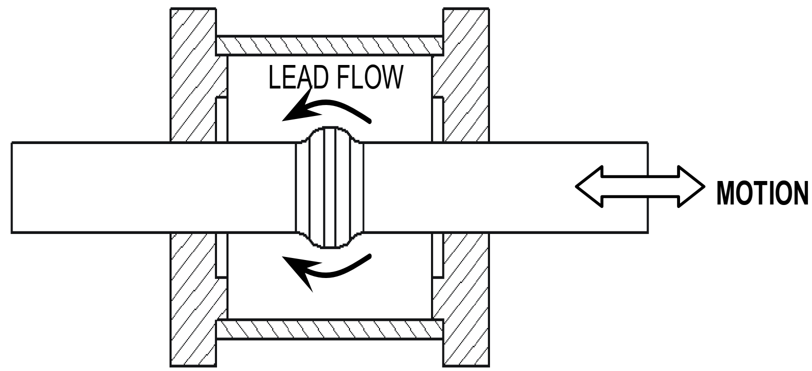
Performance Based Design

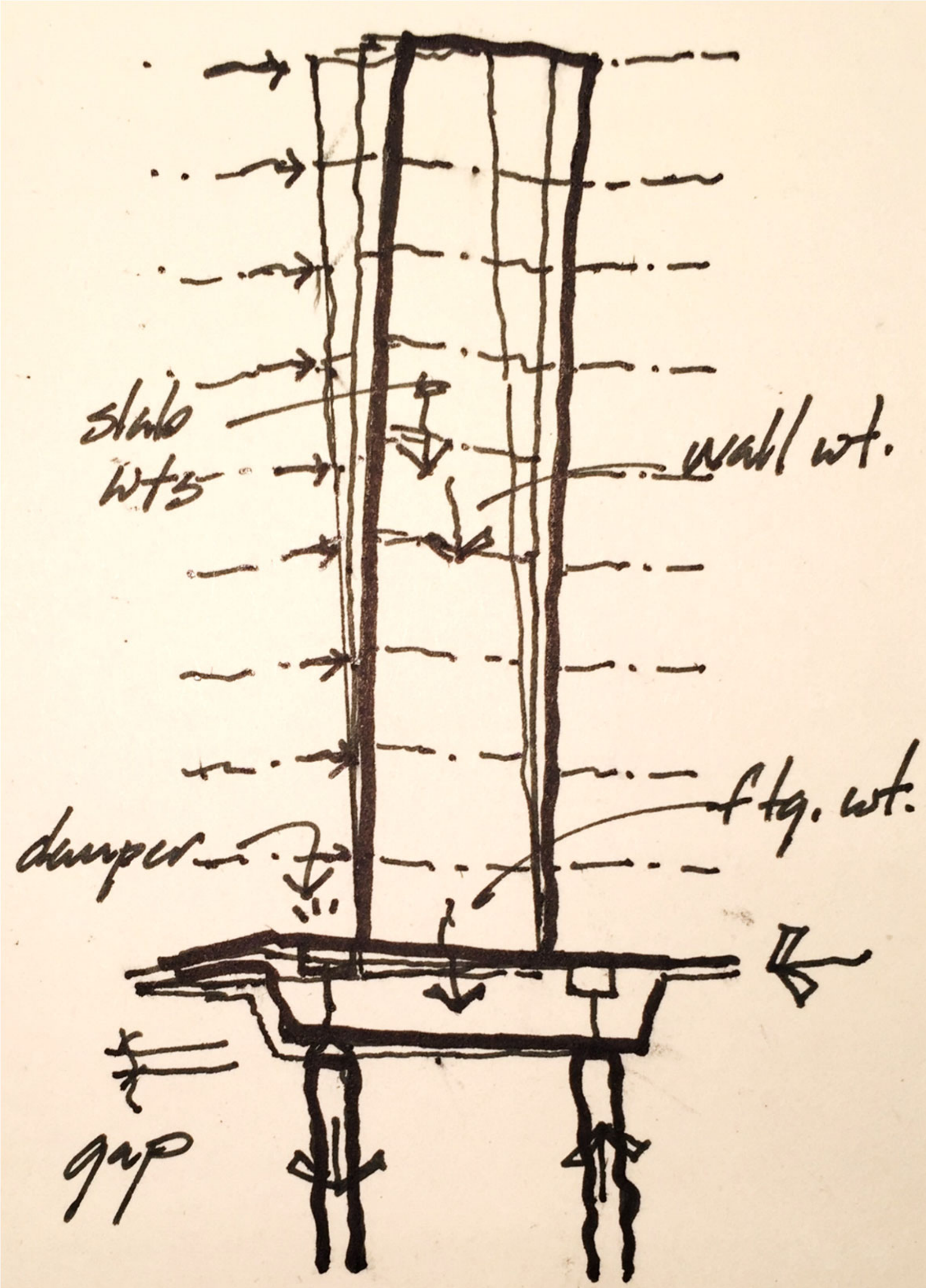


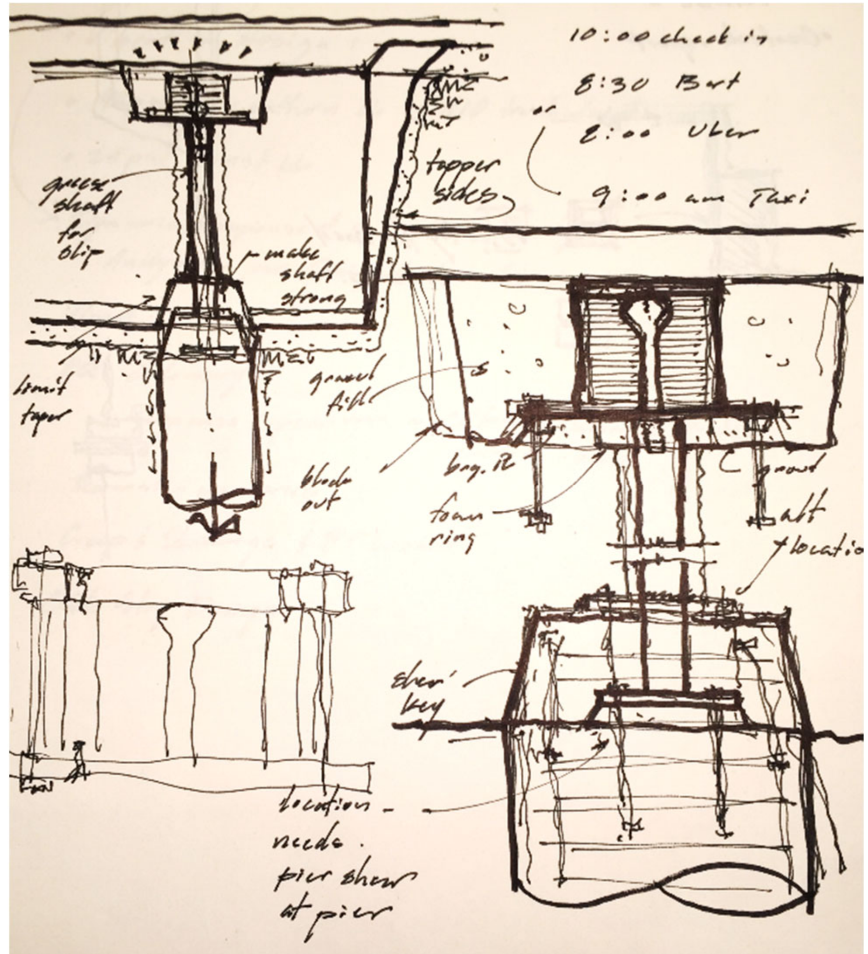
Conventional Design

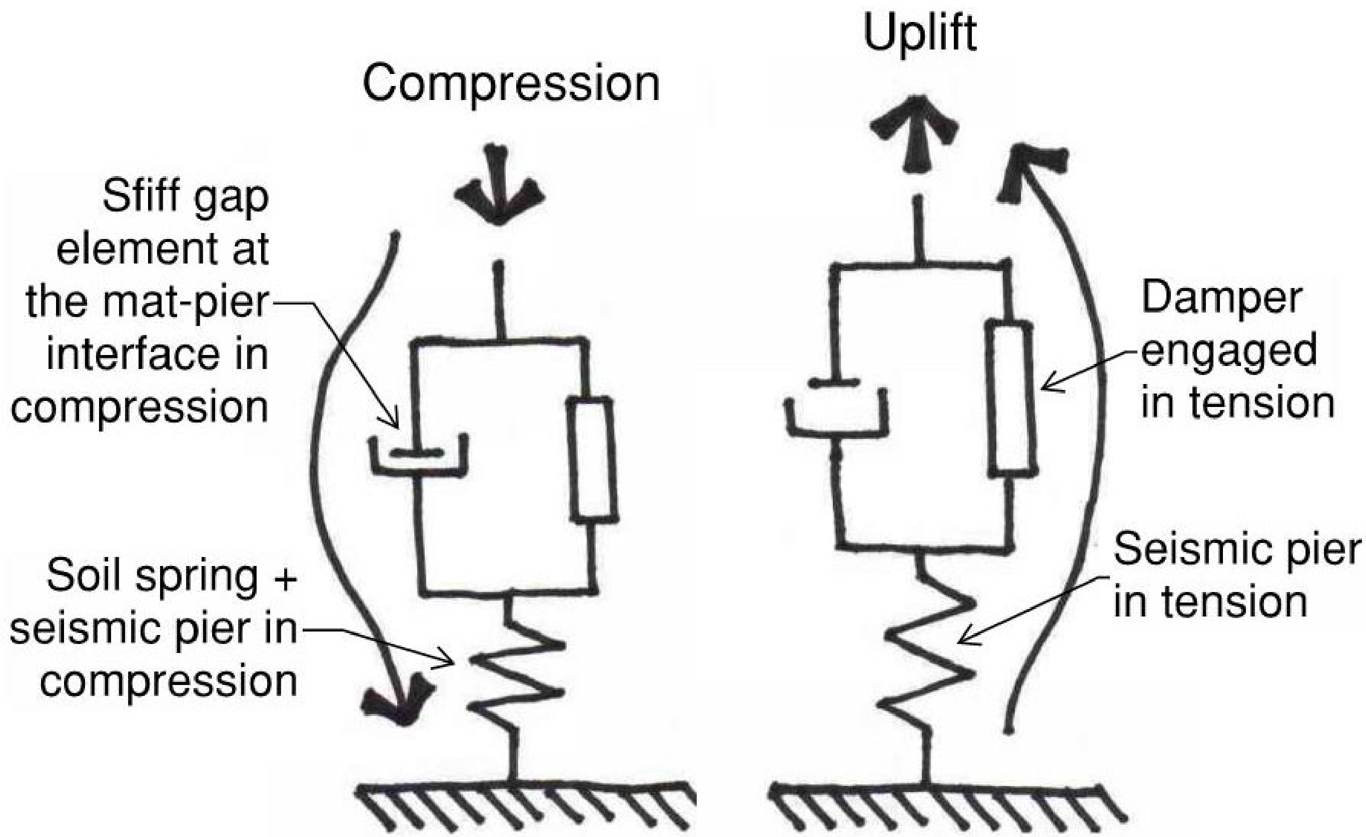





LEAD FLOW
MOTION


slab wts
wall wt.
ftg. wt.
damper
gap

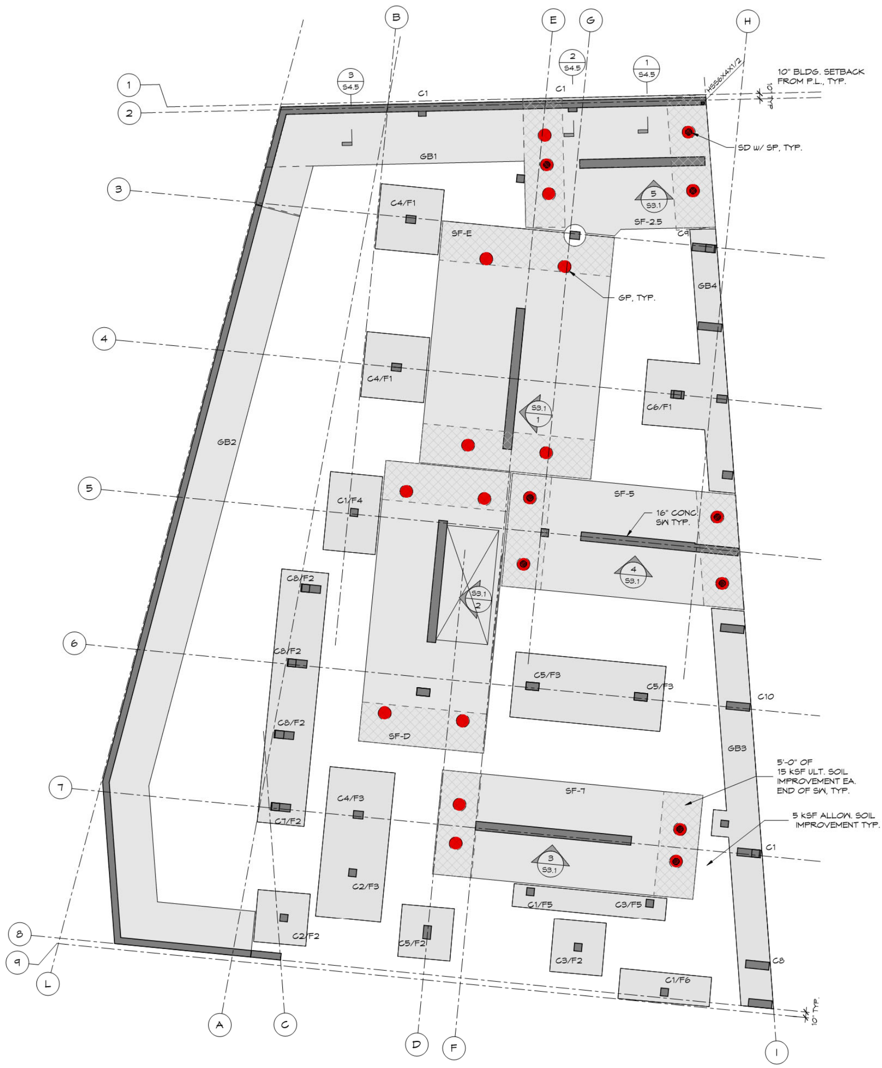

10:00 check in
8:30 Bart
2:00 Uber
9:00 am Taxi
taper sides
make shaft strong
limit taper
gravel fill
block out
form ring
grout
shear key



Compression
Uplift
Sfiff gap element at the mat-pier interface in compression
Soil spring + seismic pier in compression
Damper engaged in tension
Seismic pier in tension

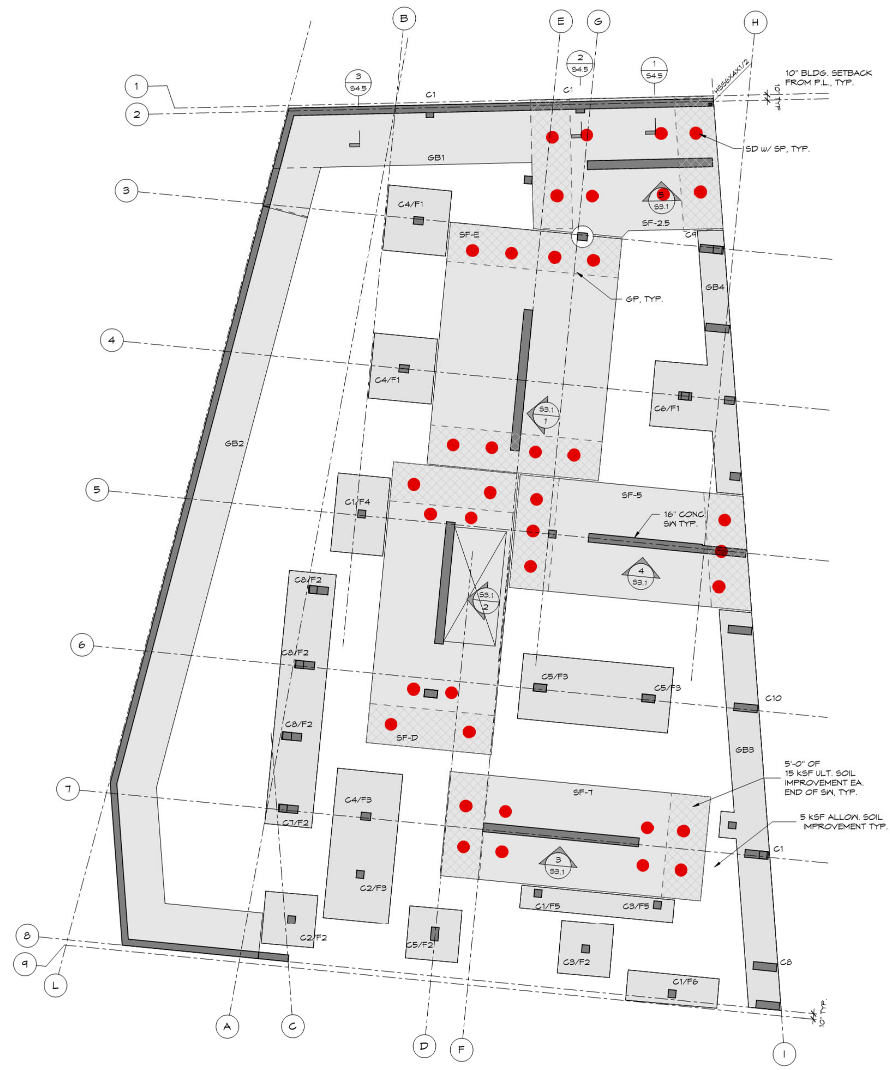
Performance Based Design

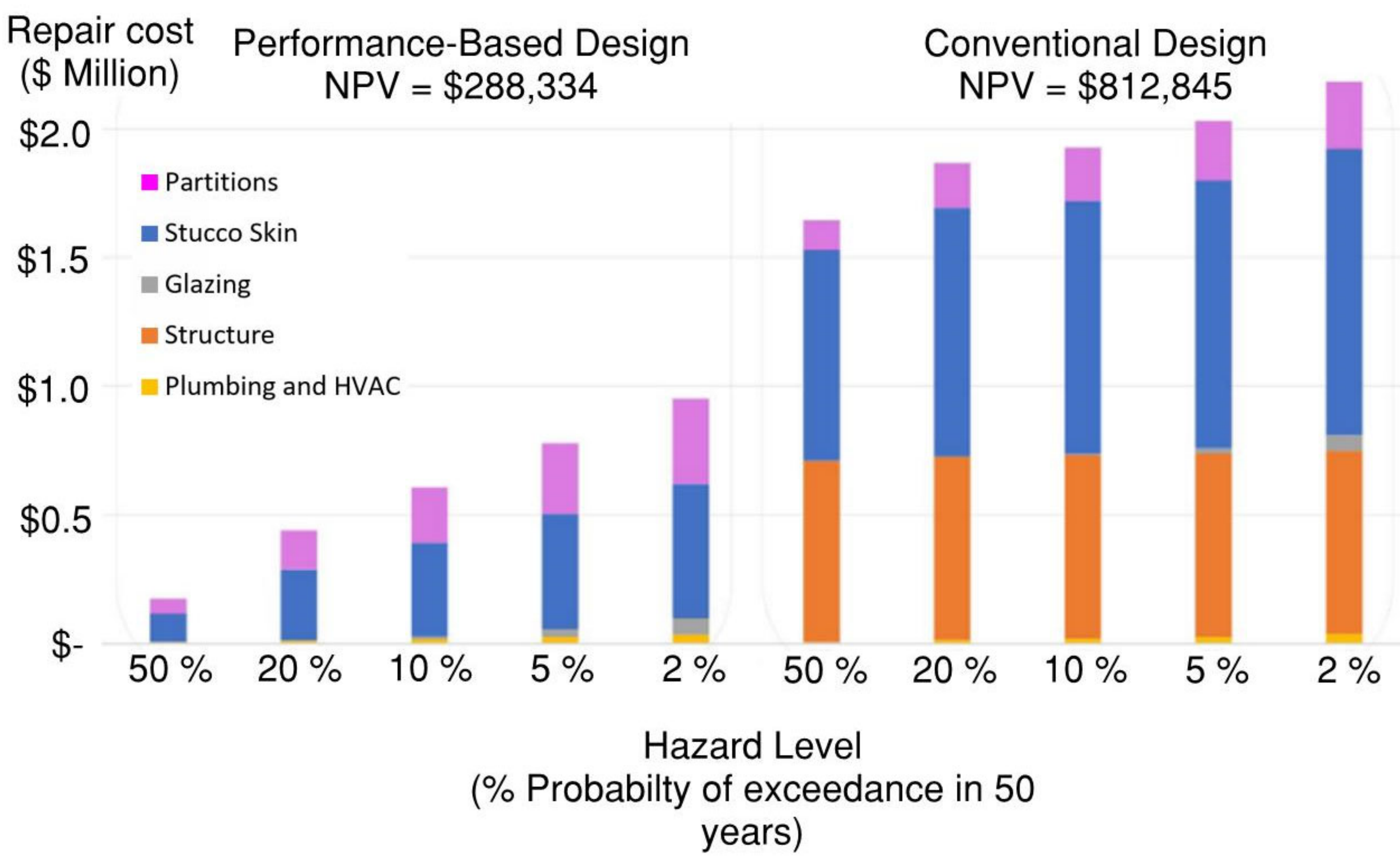
21 piers

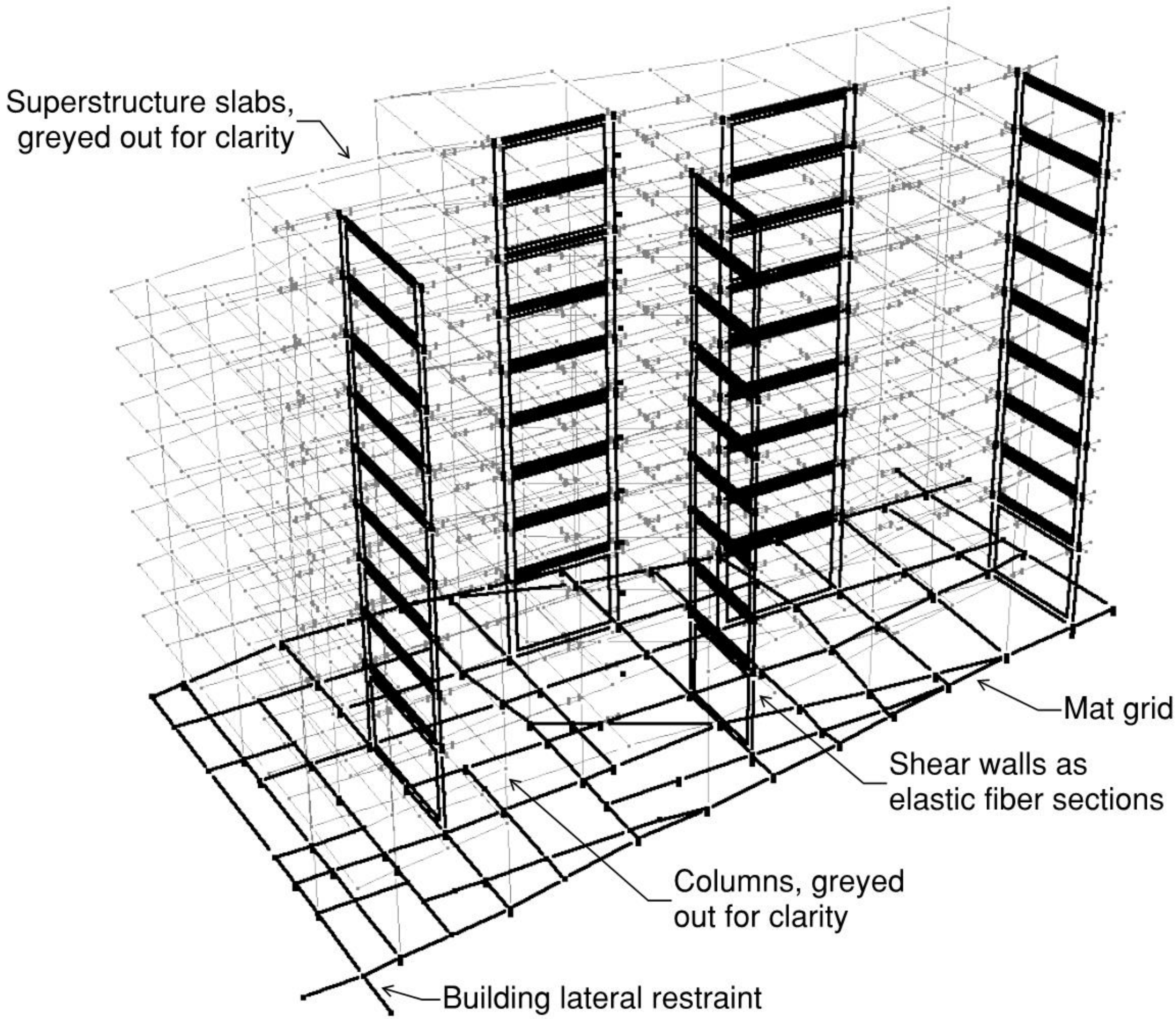


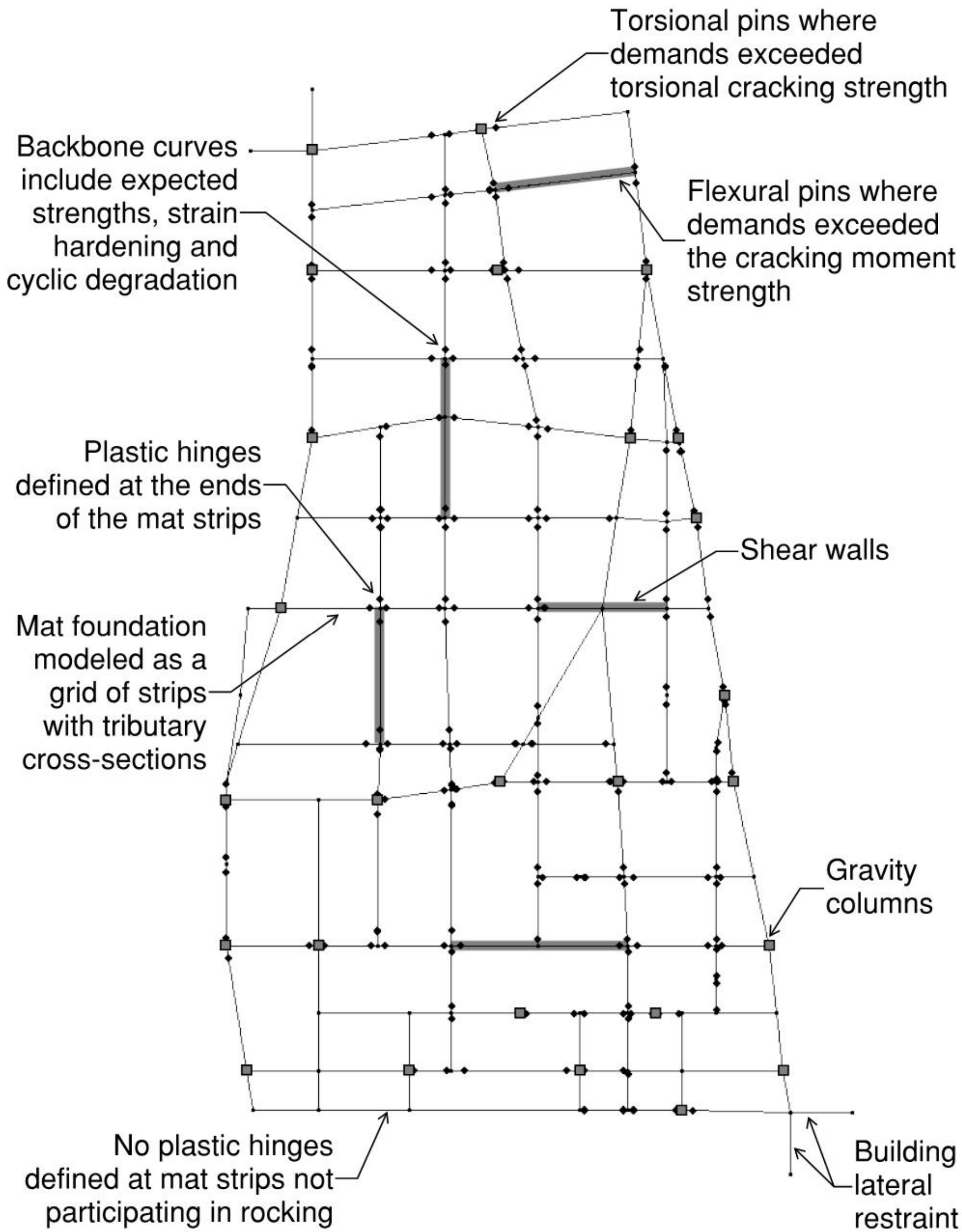
Conventional Design

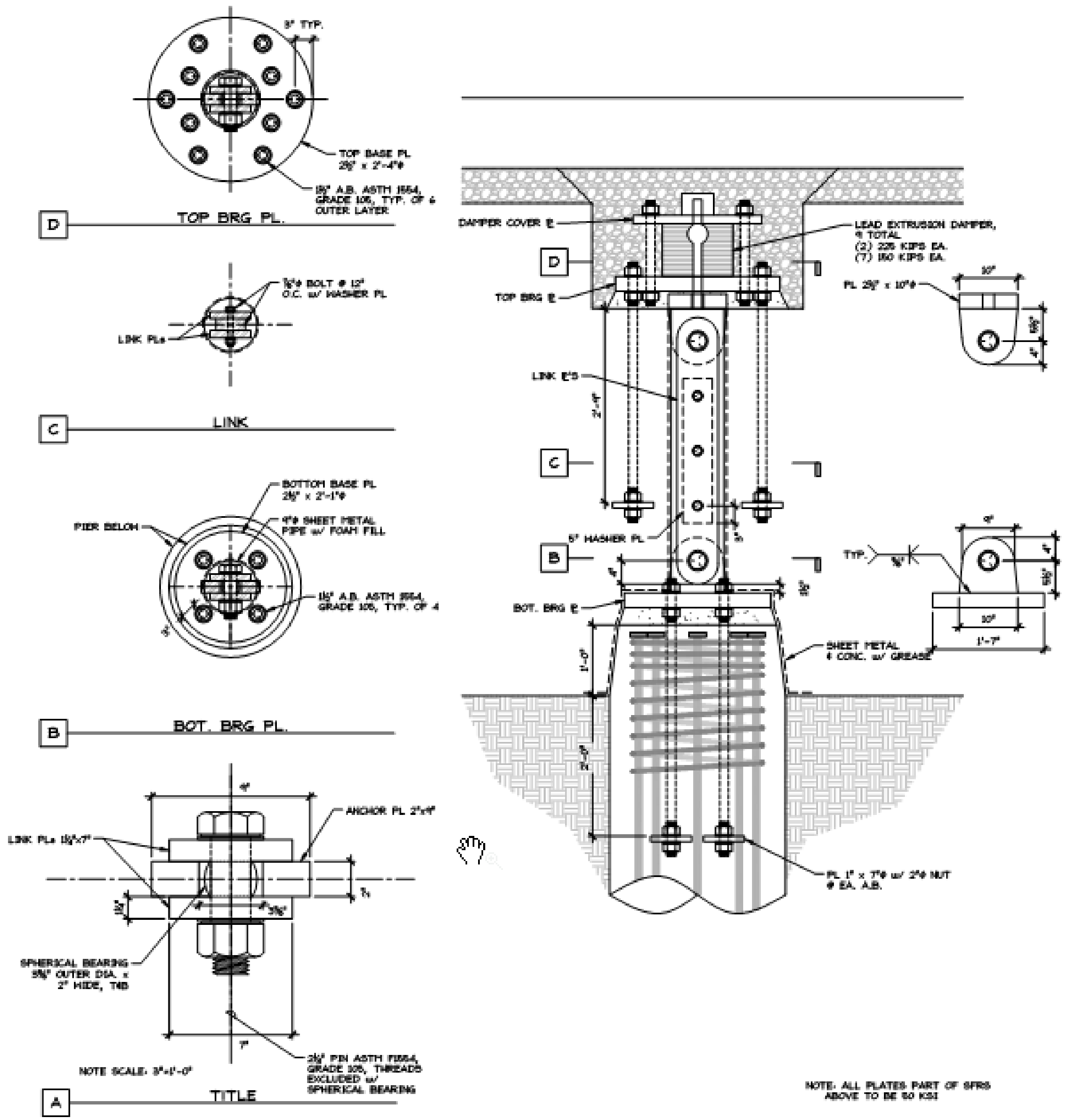
38 piers



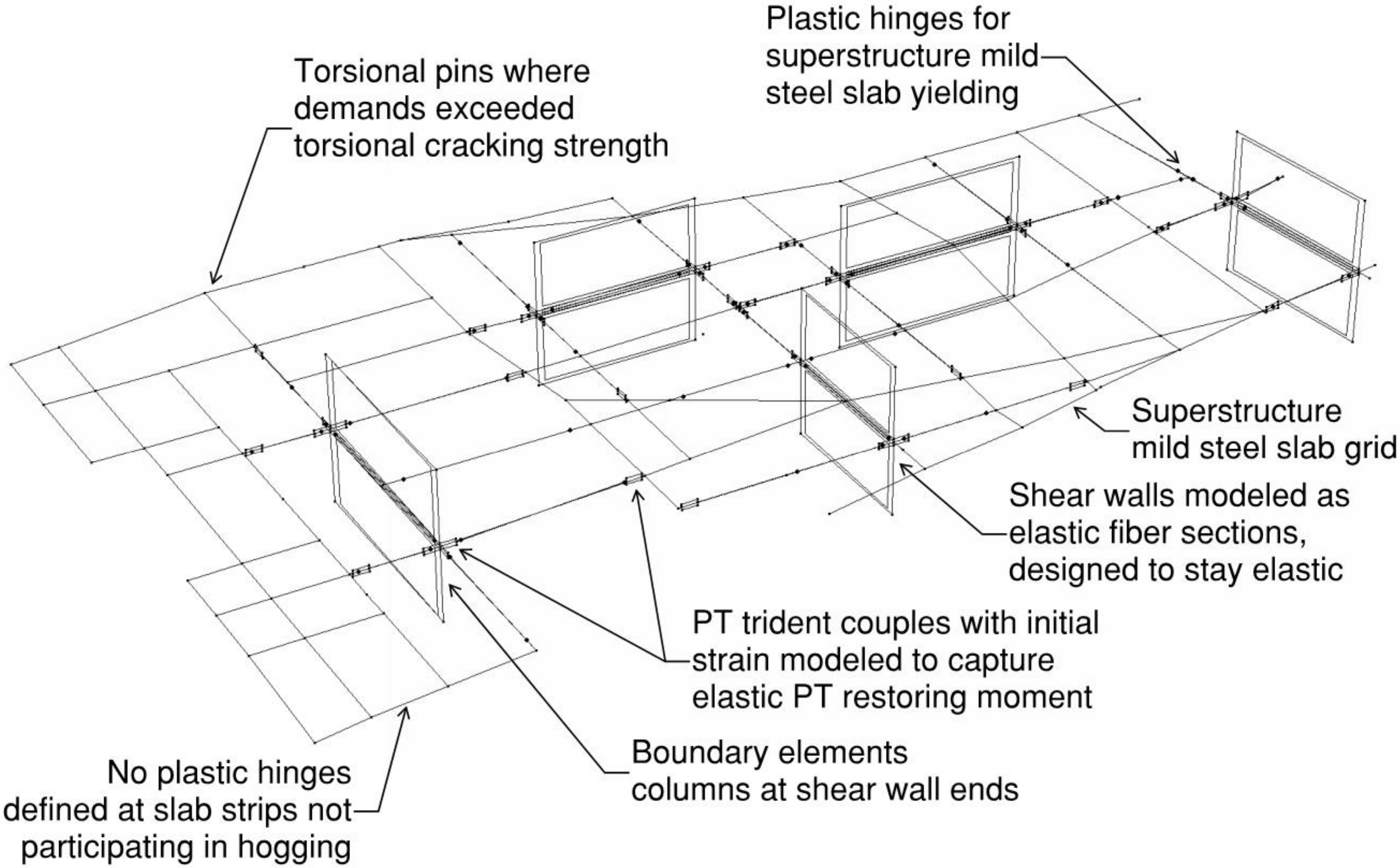

Repair cost
($ Million)
Performance-Based Design
NPV = $288,334
Conventional Design
NPV = $812,845
$2.0
$1.5
$1.0
$0.5
$-
Partitions
Stucco Skin
Glazing
Structure
Plumbing and HVAC
50 %
20 %
10 %
5 %
2 %
50 %
20 %
10 %
5 %
2 %
Hazard Level
(% Probabilty of exceedance in 50
years)


Superstructure slabs, greyed out for clarity
Mat grid
Shear walls as elastic fiber sections
Columns, greyed out for clarity
Building lateral restraint

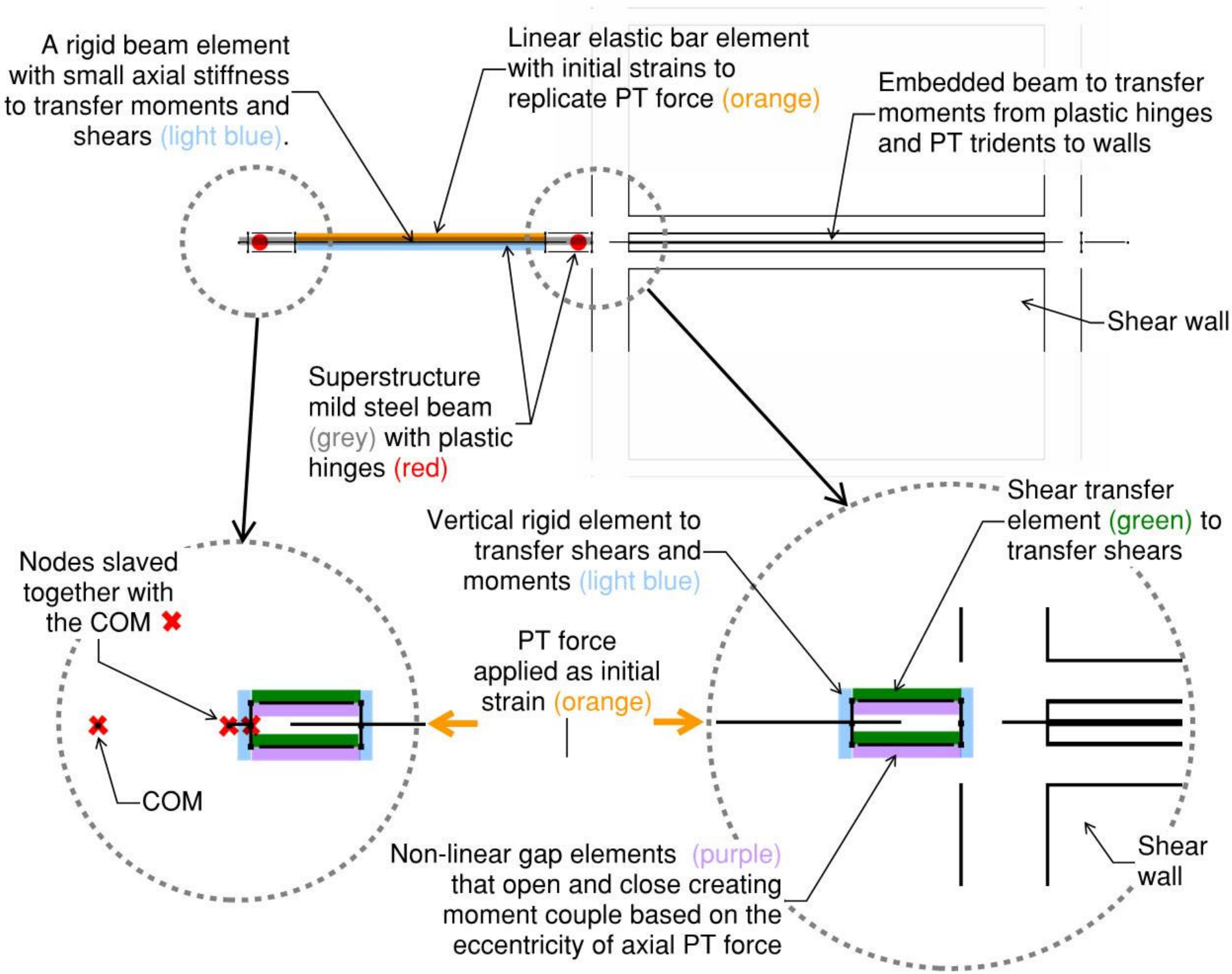

Torsional pins where demands exceeded torsional cracking strength
Backbone curves include expected strengths, strain hardening and cyclic degradation
Flexural pins where demands exceeded the cracking moment strength
Plastic hinges defined at the ends of the mat strips
Shear walls
Mat foundation modeled as a grid of strips with tributary cross-sections
Gravity columns
No plastic hinges defined at mat strips not participating in rocking
Building lateral restraint

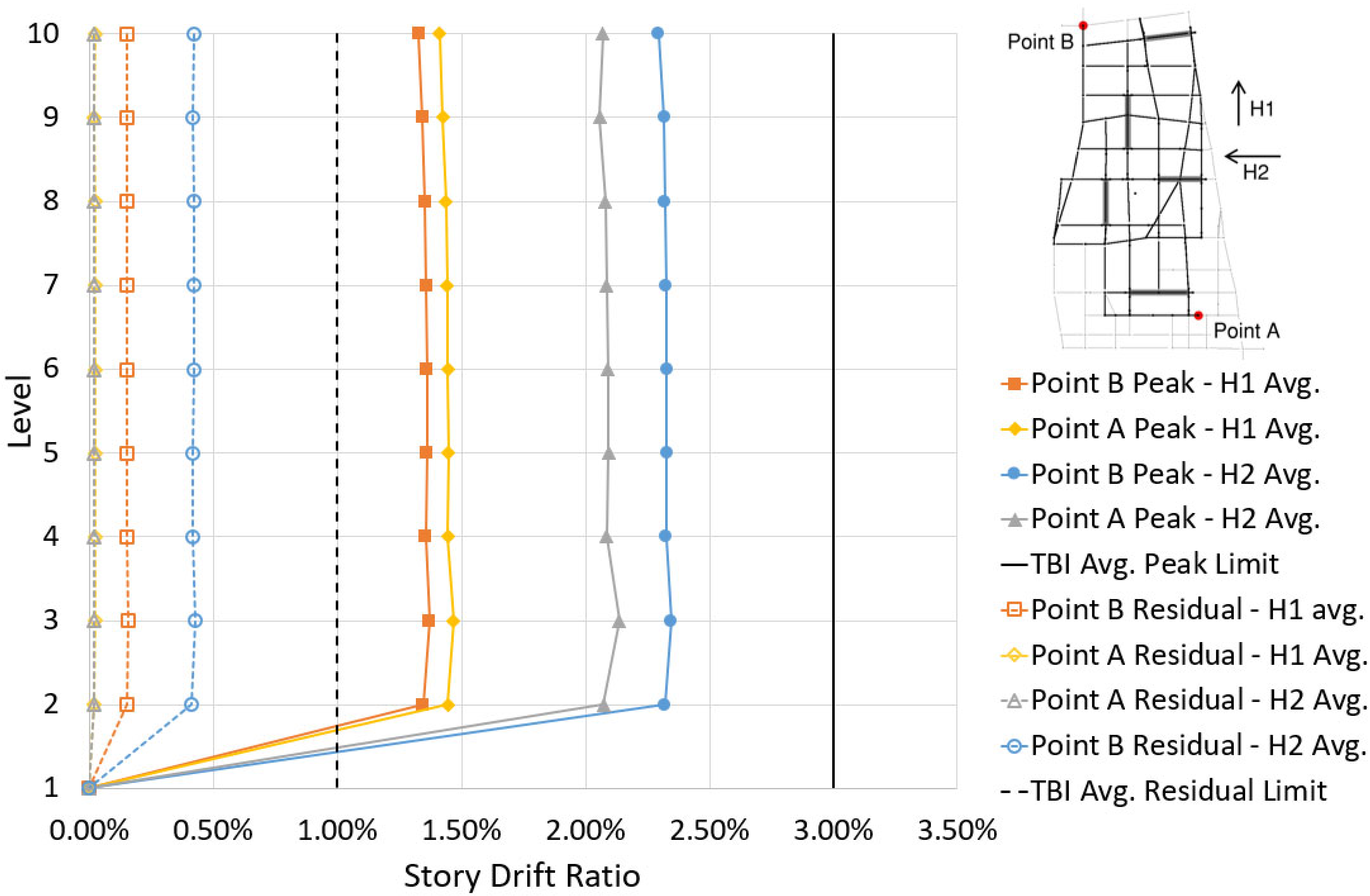


3" TYP.
TOP BASE PL
1½" A.B. ASTM F1554, GRADE 105, TYP. OF 6 OUTER LAYER
D
TOP BRG PL.
⅞"ϕ BOLT @ 12" O.C. w/ WASHER PL
LINK PLs
C
LINK
BOTTOM BASE PL
PIER BELOW
4"ϕ SHEET METAL PIPE w/ FOAM FILL
1½" A.B. ASTM F1554, GRADE 105, TYP. OF 4
B
BOT. BRG PL.
ANCHOR PL 2"x9"
LINK PLs 1½"x7"
SPHERICAL BEARING
5⅜" OUTER DIA. x
2" WIDE, T4B
2½" PIN ASTM F1554, GRADE 105, THREADS EXCLUDED w/ SPHERICAL BEARING
NOTE SCALE: 3"=1'-0"
A
TITLE
DAMPER COVER ℄
LEAD EXTRUSION DAMPER, 9 TOTAL
(2) 225 KIPS EA.
(7) 150 KIPS EA.
TOP BRG ℄
LINK ℄'S
5" WASHER PL
BOT. BRG ℄
SHEET METAL
& CONC. w/ GREASE
PL 1" x 7"ϕ w/ 2"ϕ NUT @ EA. A.B.
TYP.
1'-7"
NOTE: ALL PLATES PART OF SFRS ABOVE TO BE 50 KSI



Torsional pins where demands exceeded torsional cracking strength
Plastic hinges for superstructure mild steel slab yielding
Superstructure mild steel slab grid
Shear walls modeled as elastic fiber sections, designed to stay elastic
PT trident couples with initial strain modeled to capture elastic PT restoring moment
Boundary elements columns at shear wall ends
No plastic hinges defined at slab strips not participating in hogging

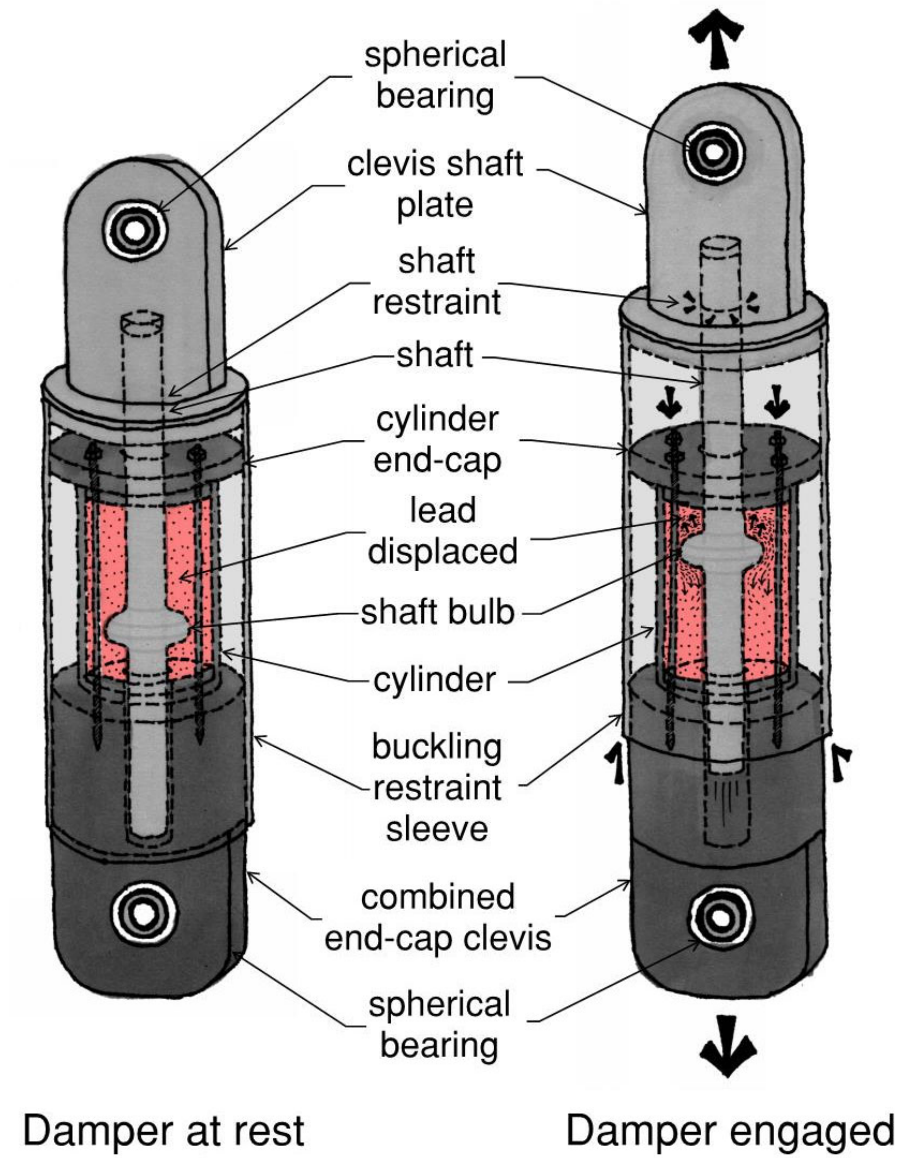

A rigid beam element with small axial stiffness to transfer moments and shears (light blue).
Linear elastic bar element with initial strains to replicate PT force (orange)
Embedded beam to transfer moments from plastic hinges and PT tridents to walls
Shear wall
Superstructure mild steel beam (grey) with plastic hinges (red)
Nodes slaved together with the COM
COM
Vertical rigid element to transfer shears and moments (light blue)
Shear transfer element (green) to transfer shears
PT force applied as initial strain (orange)
Non-linear gap elements (purple) that open and close creating moment couple based on the eccentricity of axial PT force
Shear wall

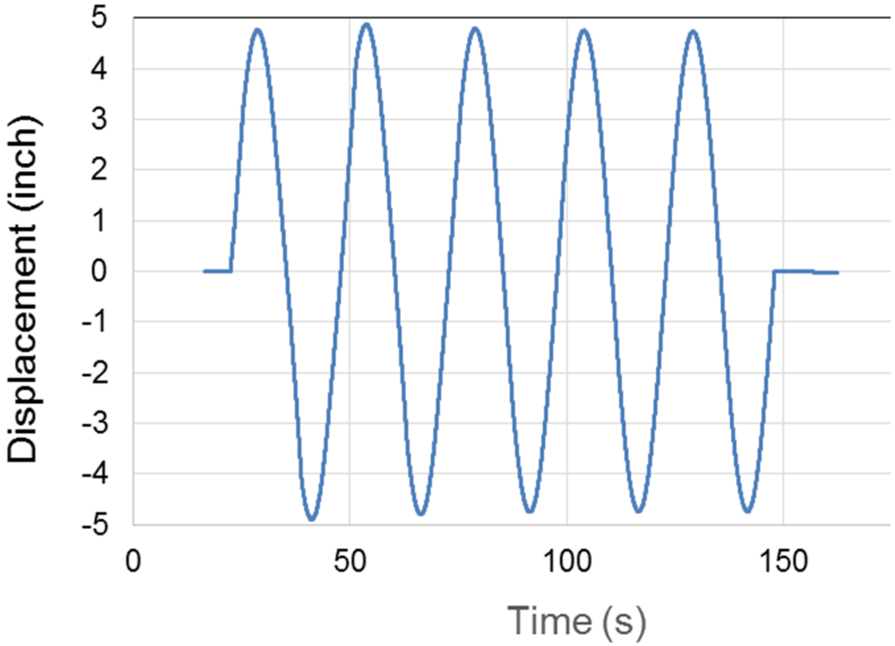


Point B
Point A
H1
H2
Level
10
9
8
7
6
5
4
3
2
1
0.00%
0.50%
1.00%
1.50%
2.00%
2.50%
3.00%
3.50%
Story Drift Ratio
Point B Peak - H1 Avg.
Point A Peak - H1 Avg.
Point B Peak - H2 Avg.
Point A Peak - H2 Avg.
TBI Avg. Peak Limit
Point B Residual - H1 avg.
Point A Residual - H1 Avg.
Point A Residual - H2 Avg.
Point B Residual - H2 Avg.
TBI Avg. Residual Limit

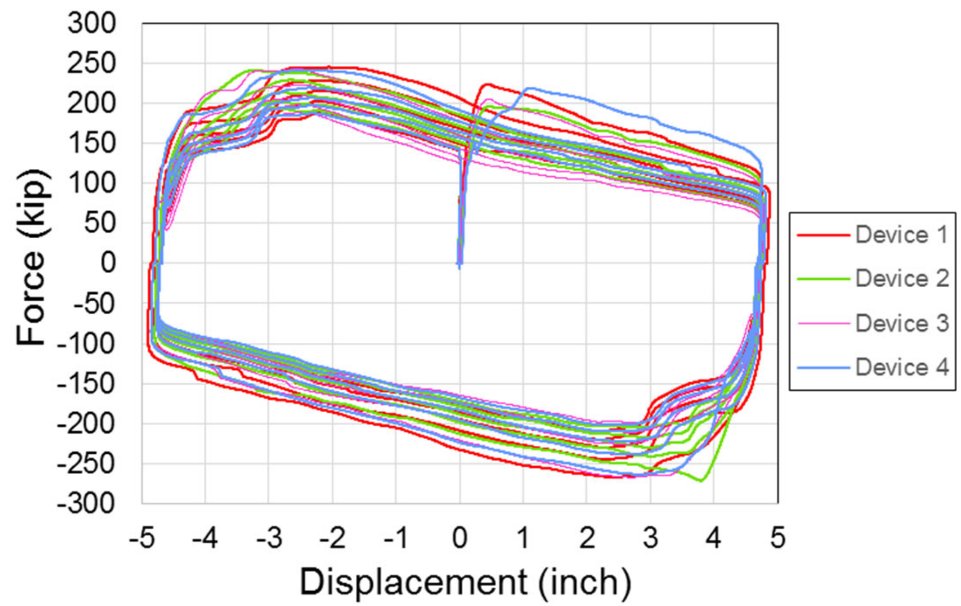
Damper
Design, Testing & Fabrication

Prof. Geoff Rogers
University of Canterbury


spherical bearing
clevis shaft plate
shaft restraint
shaft
cylinder end-cap
lead displaced
shaft bulb
cylinder
buckling restraint sleeve
combined end-cap clevis
spherical bearing
Damper at rest
Damper engaged



Displacement (inch)
Time (s)



Force (kip)
Displacement (inch)
Device 1
Device 2
Device 3
Device 4


CAHILL
Pemex
CAHILL

UC
UNIVERSITY OF
CANTERBURY

Seismic Peer Review

Pro Bono

Prof. Greg Deierlein
Stanford University