THE ROLE OF STRUCTURAL ENGINEERING EDUCATION
TWO PRACTITIONER PERSPECTIVES

PETER LEE AND NEVILLE MATHIAS

Retirement Symposium and Celebration
For Professor Chopra
03 October 2017

SOM

Bechtel Engineering Center, Sibley Auditorium
University of California, Berkeley

So, how has our education at UCB influenced our work and careers?

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EARTHQUAKE ENGINEERING

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So, how has our education at UCB influenced our work and careers?

EARTHQUAKE ENGINEERING

TECHNOLOGY & INNOVATION

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CAREER FOCUS

SOM

SAN DIEGO CENTRAL COURTHOUSE

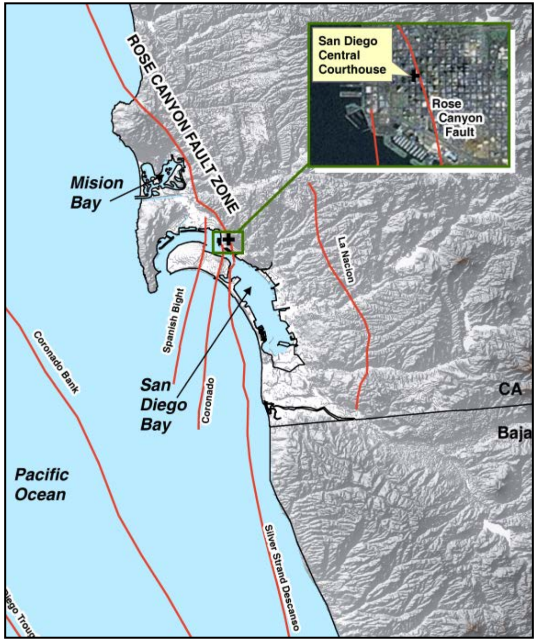
SOM

San Diego Central Courthouse

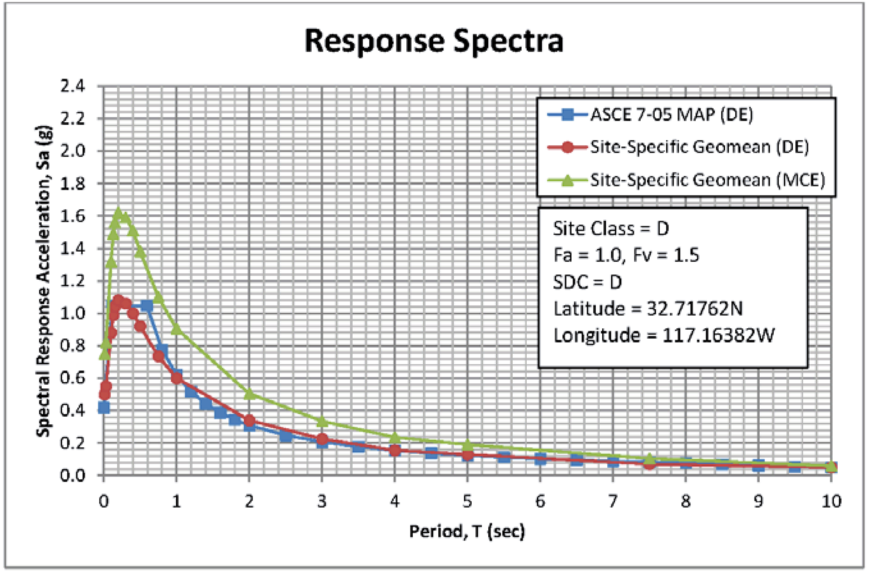
A few topics,

- Overall description
- Nonlinear response history analysis
- Effectiveness of VDD in wind
- Steel SMF connection qualification

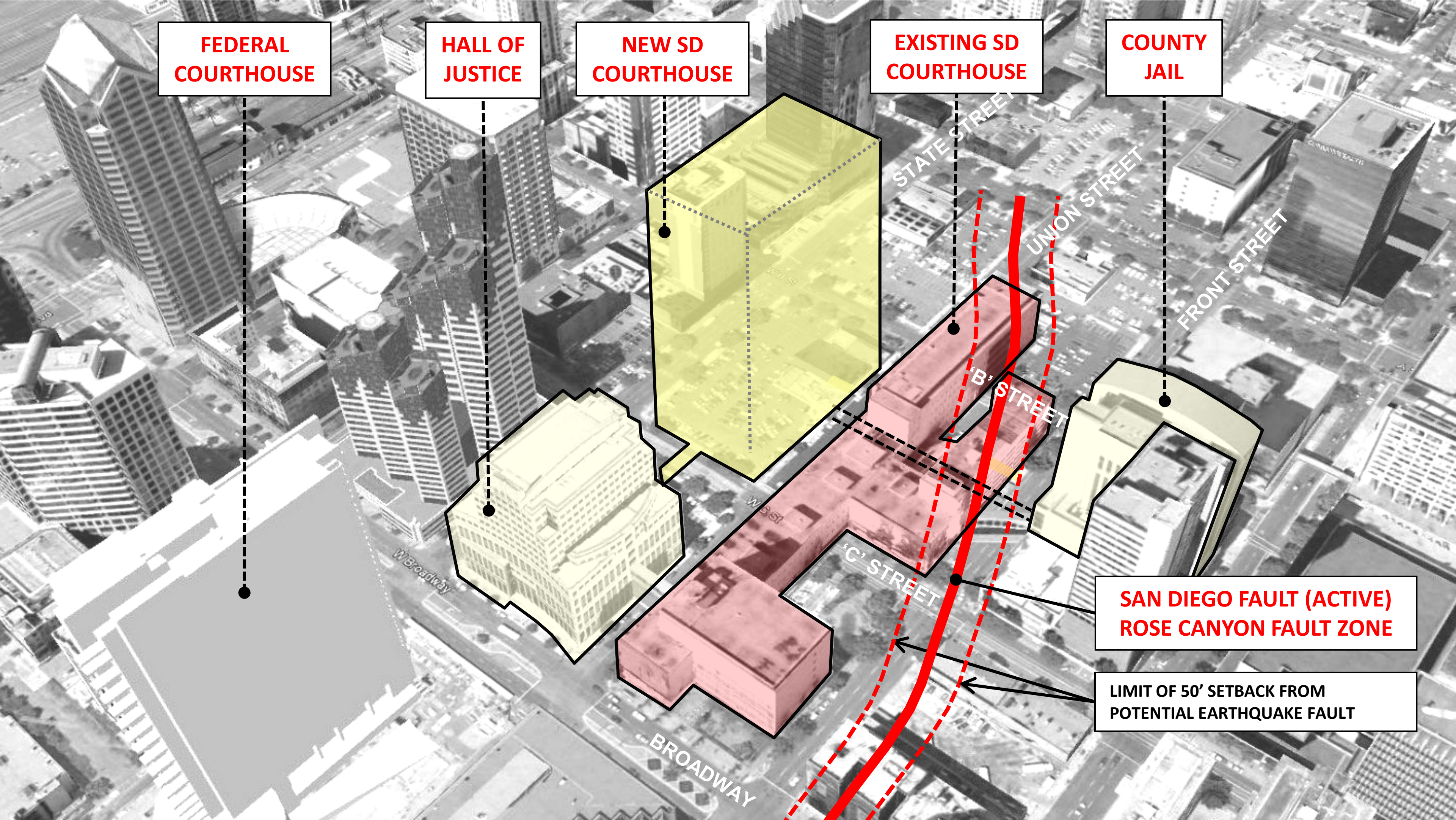
Site Seismicity and Ground Motions



Regional faults & sources
(URS, 2012)



Site-specific PSHA response spectra
DE (475 yr) & MCE (2475 yr)
(URS, 2012)



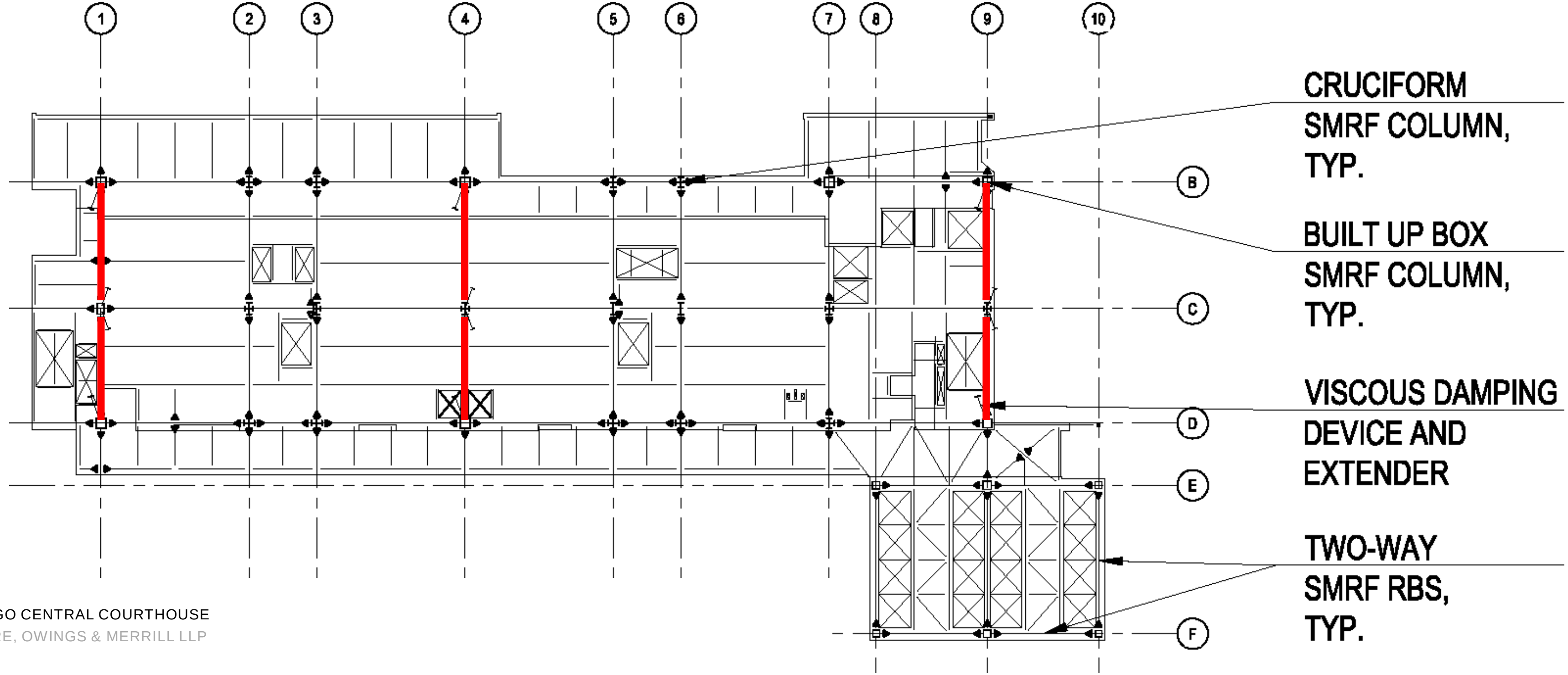
FEDERAL COURTHOUSE
HALL OF JUSTICE
NEW SD COURTHOUSE
EXISTING SD COURTHOUSE
COUNTY JAIL
STATE STREET
UNION STREET
FRONT STREET
'B' STREET
'C' STREET
BROADWAY
W Broadway
SAN DIEGO FAULT (ACTIVE)
ROSE CANYON FAULT ZONE
LIMIT OF 50' SETBACK FROM
POTENTIAL EARTHQUAKE FAULT

Steel Framed Superstructure

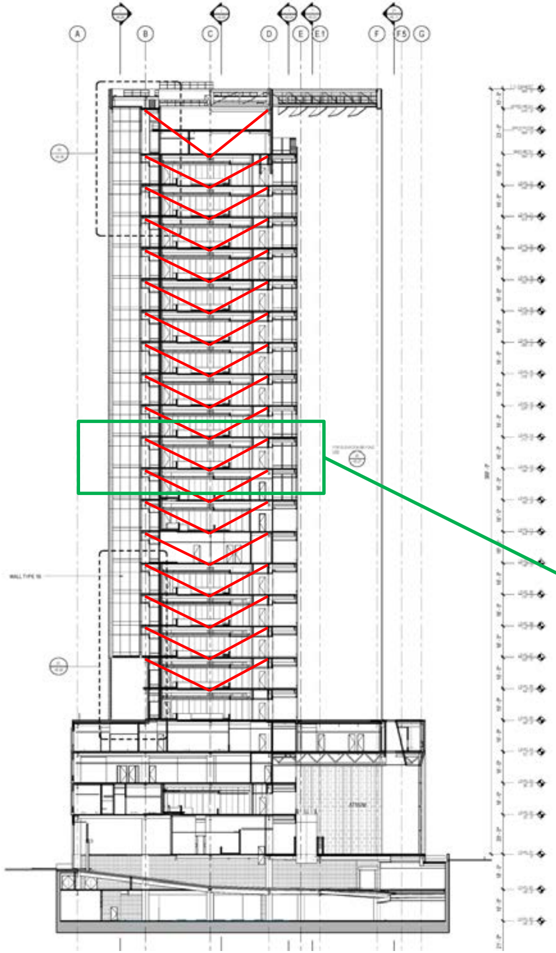
- 24 story & two below grade basement levels
- 389 feet to top of roof parapet
- 704,000 gross sq ft
- Typical four courtrooms per level
- 16 ft floor-to-floor height
- Steel superstructure with composite WF floor slab construction
- Two-way Special Moment Frames (SMF) lateral resisting frames + supplemental viscous damping devices (VDD)

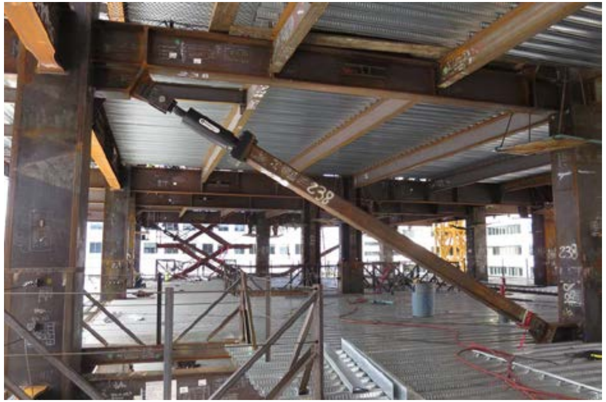
Typical Framing Plan at Tower Level

- 106 viscous damping devices (VDD)
- Distributed typically 6 per level at levels 6 to 24
- 330 kip & 440 kip VDDs (4 & 5 inch stroke capacity)

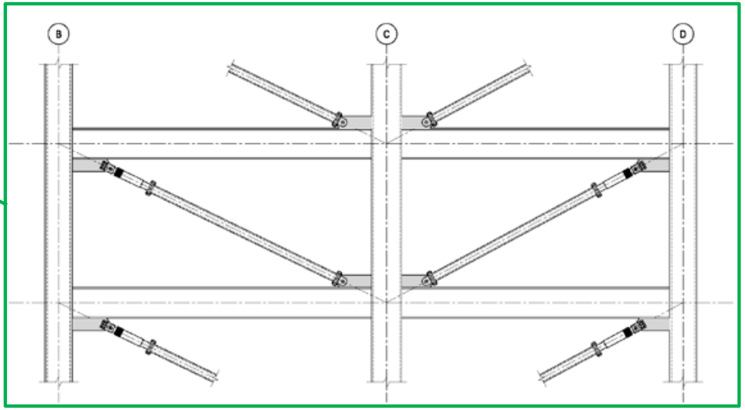


Supplemental Damping Using SMF + VDDs



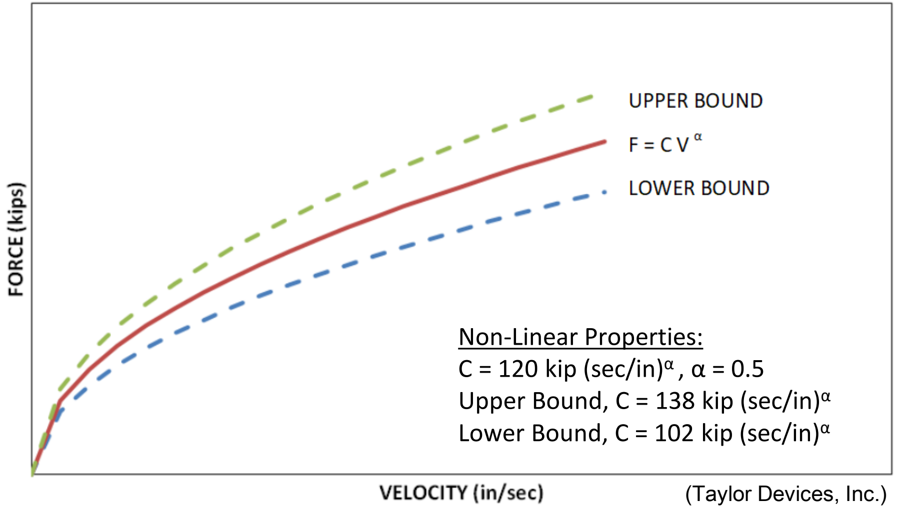


TYPICAL INSTALLED DIAGONAL DAMPER
& EXTENDER BRACE (SAN DIEGO COURTHOUSE)



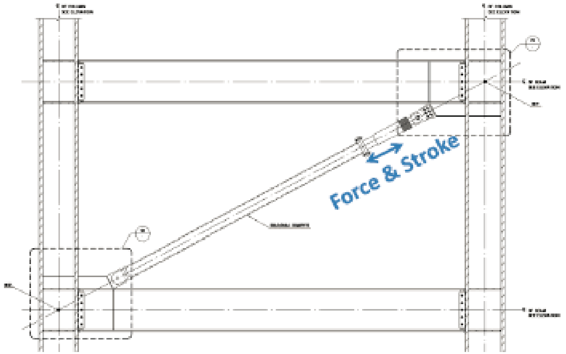
TYPICAL DAMPER & EXTENDER BRACE
DIAGONAL FRAME CONFIGURATION

Viscous Damping Device (VDD) Properties

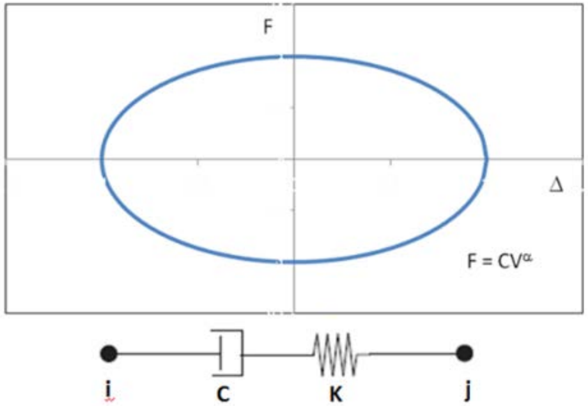


(Taylor Devices, Inc.)

VDD Bounded Properties (+/- 15% ASCE 7)

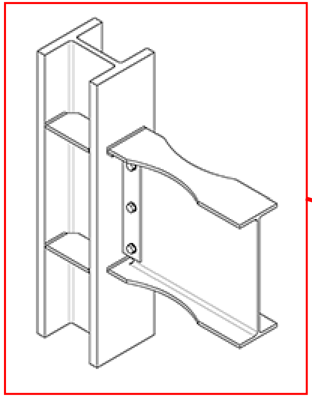


- ETABS v9.7 (CSI)
- VDD + HSS Extender = Series Combination
- VDD Force, $F = Cv^{\alpha}$

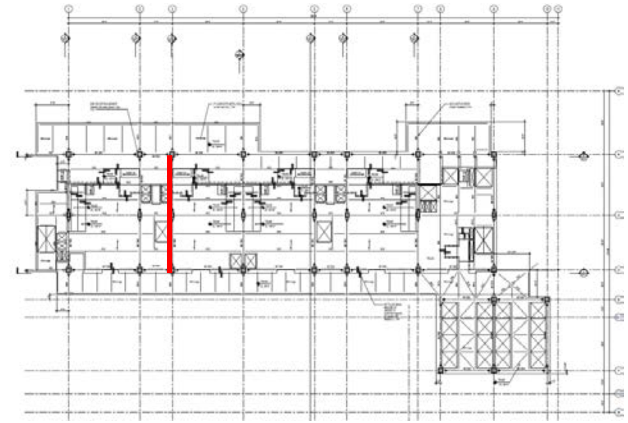


Idealized linear behavior of VDD

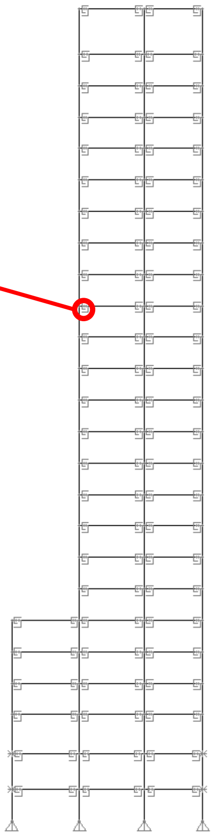
Inelastic SMF "RBS" Beam Modeling



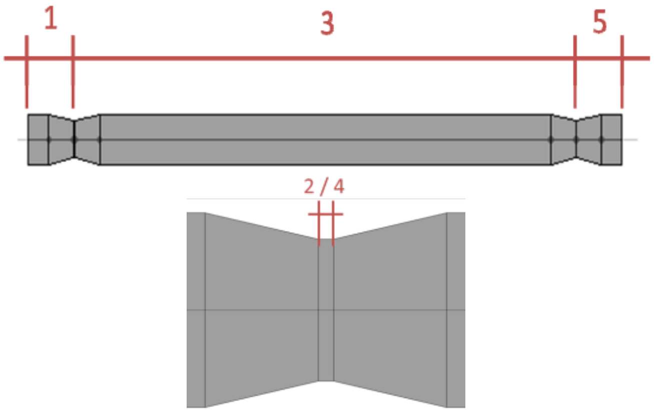
RBS NONLINEAR LINK



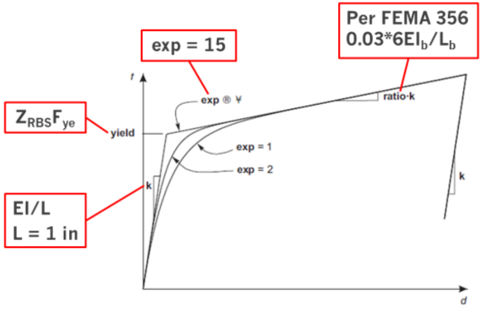
SAN DIEGO CENTRAL COURTHOUSE
SKIDMORE, OWINGS & MERRILL LLP



TRANSVERSE
MOMENT FRAME
ELEVATION



RBS "plastic hinge" beam segment definition (ETABS NL v9.7)

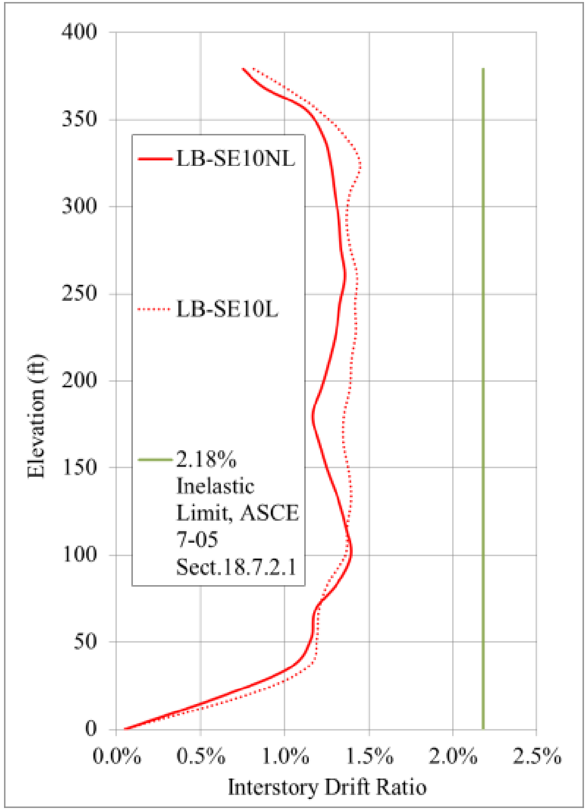


$\Phi_{DE} < 6\ \Phi_Y$

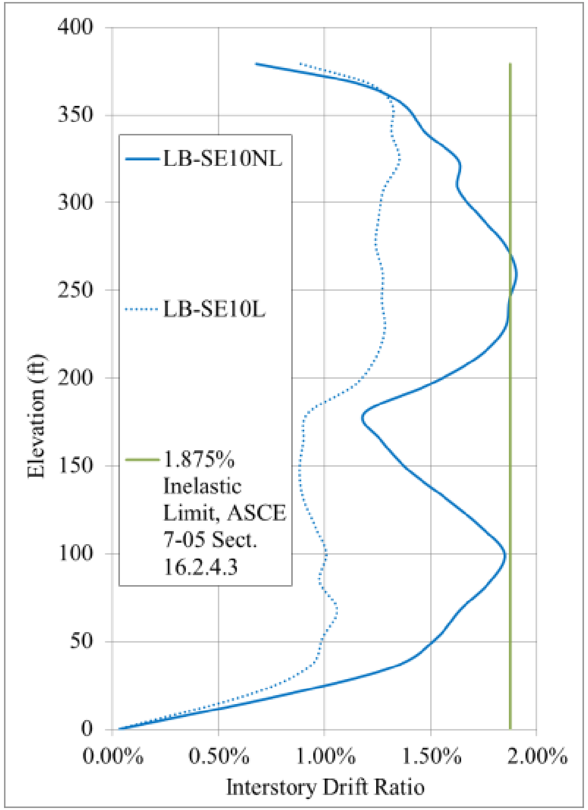
$\Phi_{MCE} < 8\ \Phi_Y$

Nonlinear moment-rotation link definition (FEMA 356)

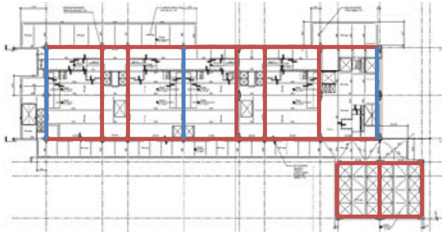
Enhanced Performance Summary Results (DE)



Transverse DE story drift

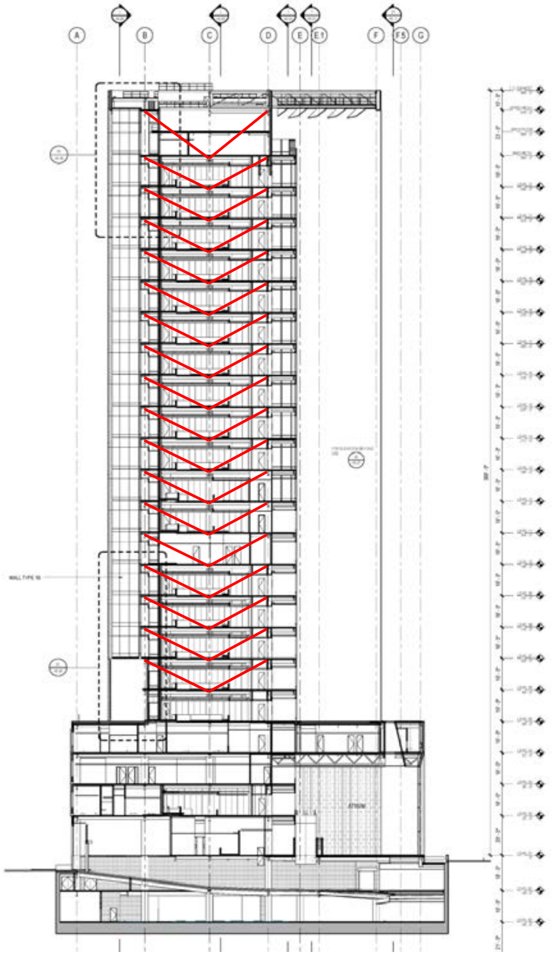


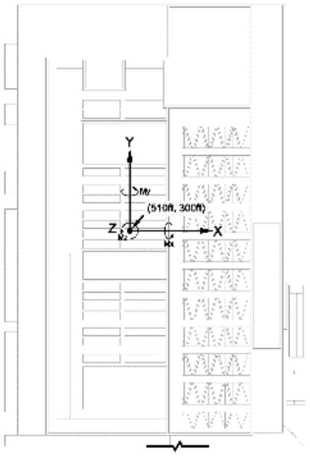
Longitudinal DE story drift



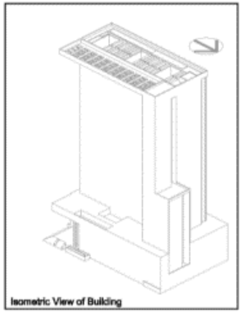
EFFECTIVENESS OF VISCOUS DAMPING DEVICES UNDER WIND

Wind Tunnel Modeling



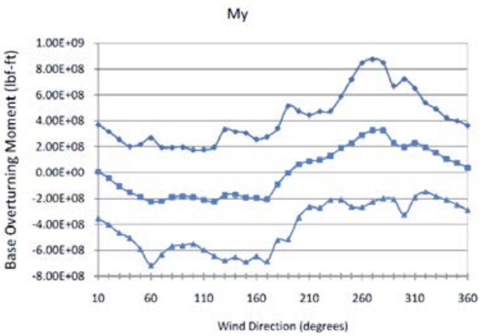


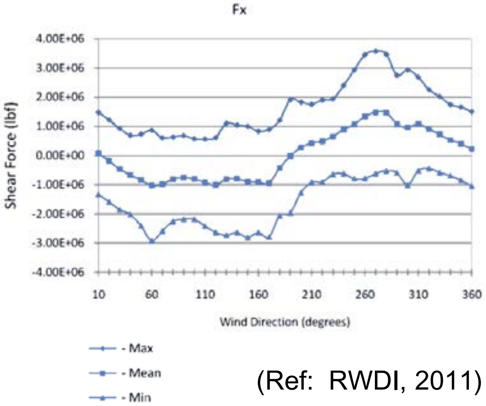
ROOF PLAN



Return Period (Years)	Moments			Shears	
	My (lb-ft)	Mx (lb-ft)	Mz (lb-ft)	Fx (lb)	Fy (lb)
50	7.30E+08	4.02E+08	1.22E+08	2.99E+06	1.61E+06
20	3.34E+08	1.96E+08	5.61E+07	1.48E+06	8.53E+05
10	3.02E+08	1.75E+08	5.20E+07	1.37E+06	7.80E+05

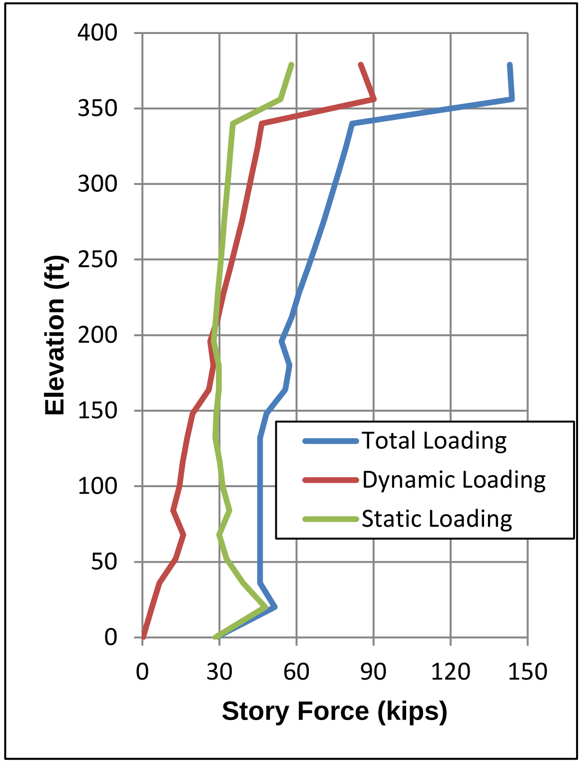
Predicted Peak Resultant Structural Wind Loads at Base (ζ = 1.5%)



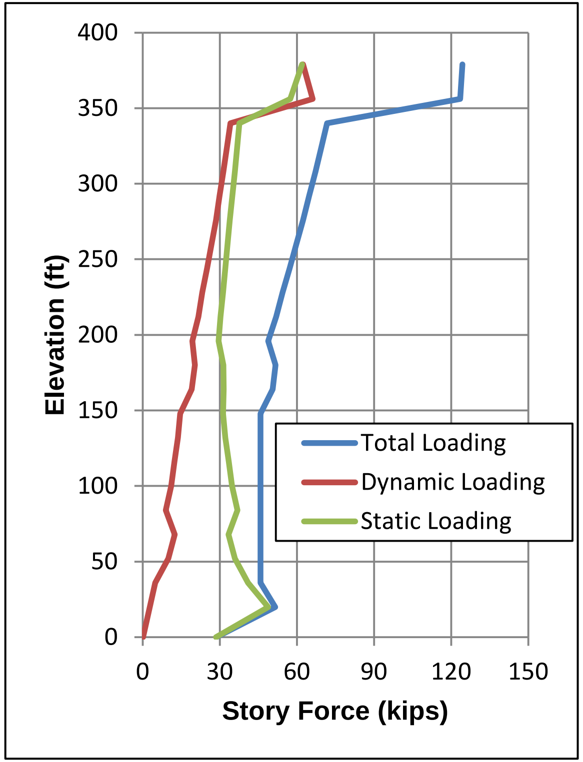


(Ref: RWDI, 2011)

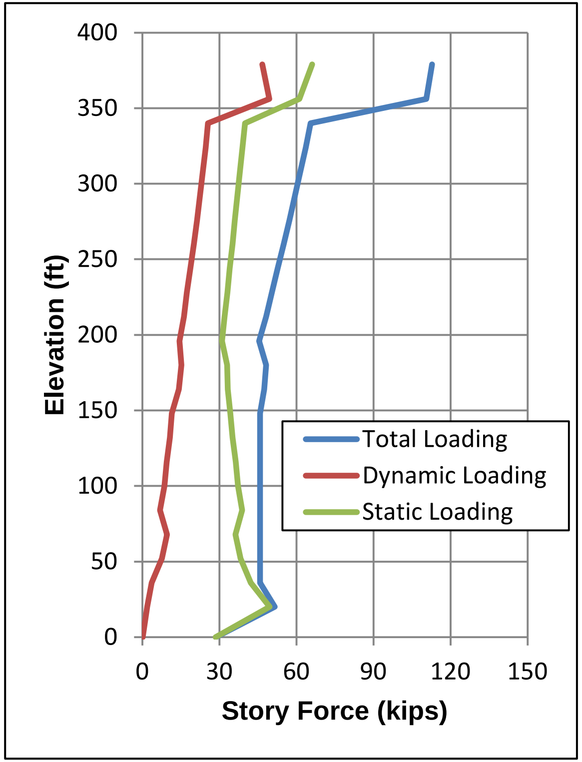
20 Year Return Period Wind Force (RWDI)



1.5% Damping Ratio

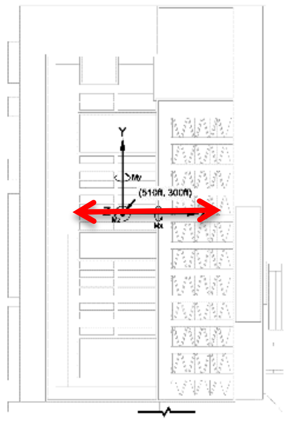


3.0% Damping Ratio

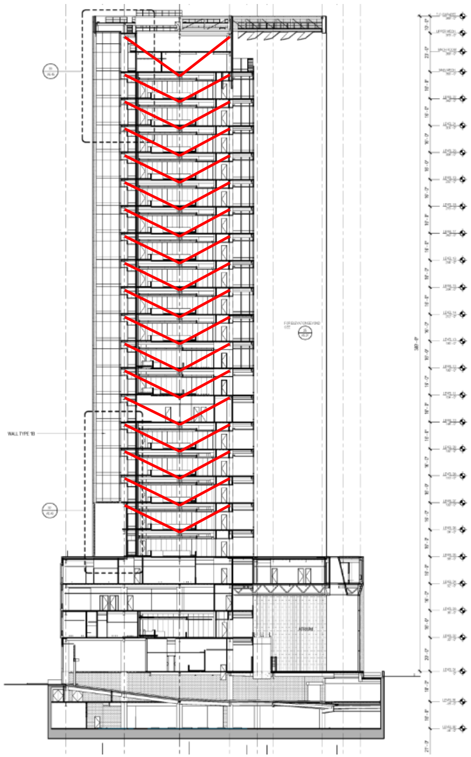


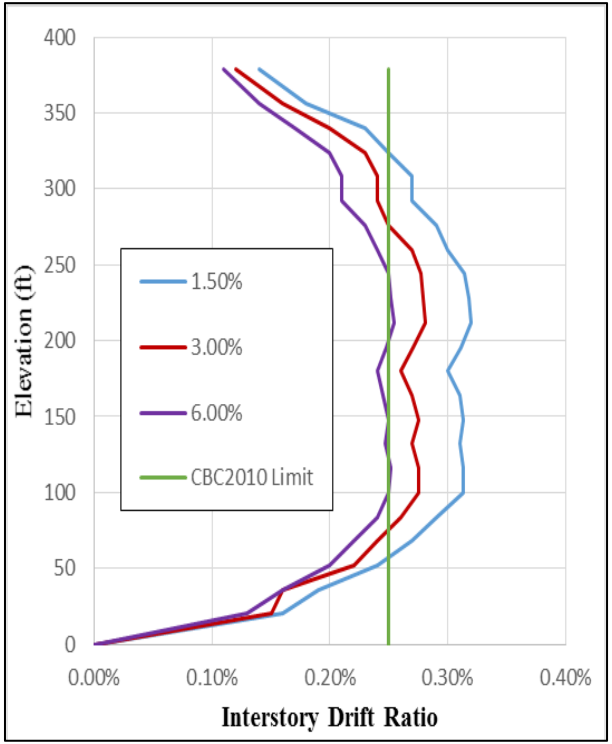
6.0% Damping Ratio

Inter-story Drift Ratio (20 year return)



ROOF PLAN





SAN DIEGO CENTRAL COURTHOUSE

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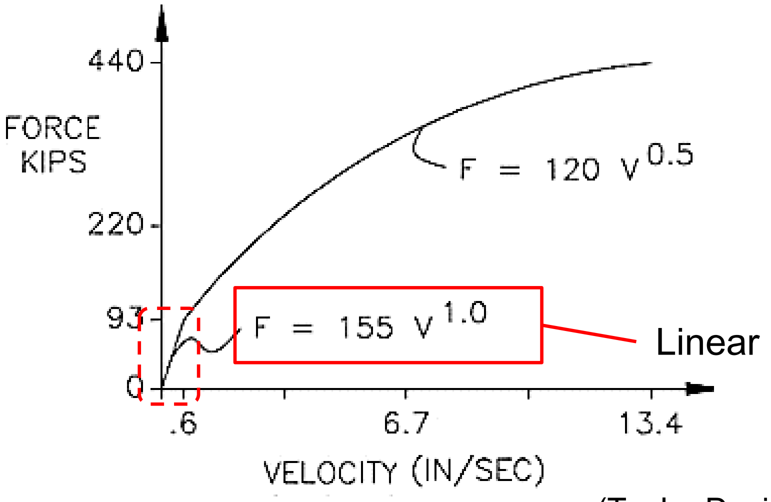
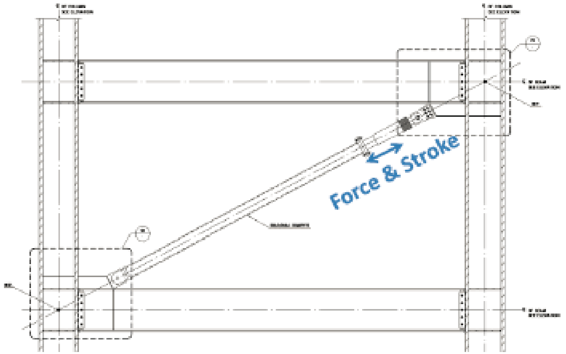
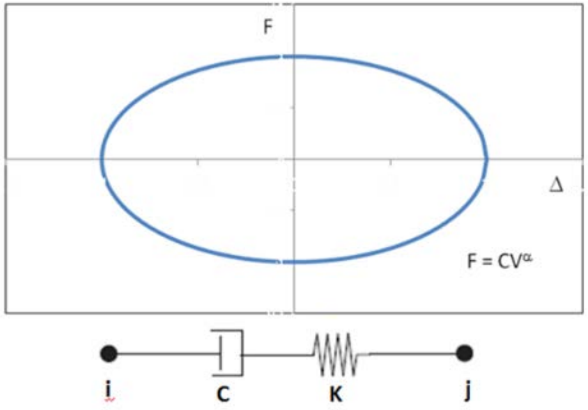
Viscous Damping Device (VDD) Properties



(Taylor Devices, Inc.)





Idealized linear behavior of VDD

Additional Damping Ratio Analytical Studies

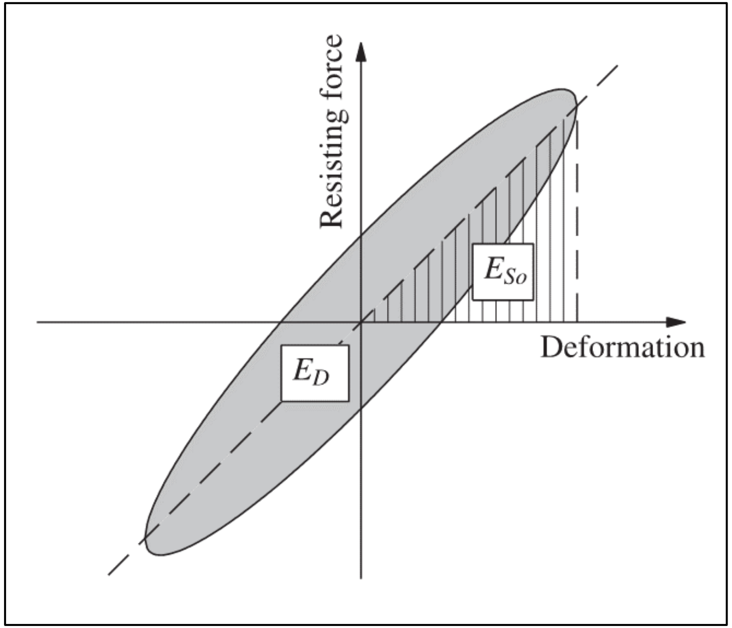
- Inherent damping ratio = 1.5%

- VDDs provide additional damping ratios

$$\zeta_{eq} = \frac{1}{4\pi}\frac{E_D}{E_{So}}$$

E_{So} = total available potential energy

E_D = dissipated energy in one cycle of displacement



Energy Loss in a Cycle of Harmonic Vibration and Total Available Potential Energy

(Ref. Dynamics of Structures, A.K. Chopra)

VDD Modal Damping Properties

$$\zeta_{eq} = \frac{1}{4\pi}\frac{\sum E_D}{\sum E_{So}}$$

E_{So} = total available potential energy

$$E_{So} = \frac{1}{2}M\phi_{XY}^2\omega^2$$ for translational mode shape

$$E_{So} = \frac{1}{2}I_{CM}\emptyset_R^2\omega^2$$ for rotational mode shape

$$\omega = \frac{2\pi}{T}$$

T = modal period

ΦXY = modal translation displacement of diaphragm

ΦZ = modal rotation of diaphragm

M = diaphragm mass

ICM = mass moment of inertia

Data extracted from ETABS model

E_D = sum of dissipated energy in VDDs

$$E_D = \pi C\omega\phi^2$$

$$\omega = \frac{2\pi}{T}$$

T = modal period

Φ = modal deformation of VDD

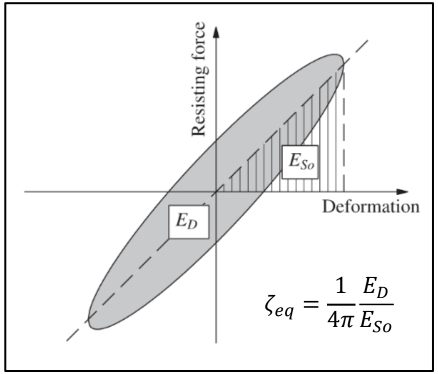
Data extracted from ETABS model

Additional Modal Damping Ratios (VDD)

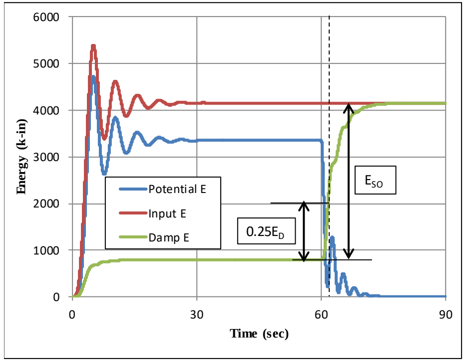
Mode	Period (sec)	Type	E_D (kip-in)	E_S (Trans) (kip-in)	E_S (Torsion) (kip-in)	ζ
1	5.22	Y	0.01	0.72	0.00	0.1%
2	4.73	X	1.25	0.86	0.03	11.2%
3	4.44	T	2.08	0.22	0.79	16.4%
4	1.91	Y	0.33	5.36	0.07	0.5%
5	1.76	X-T	33.76	3.52	2.94	41.6%
6	1.67	X-T	40.8	4.67	2.50	45.3%
7	1.36	Vertical	0.00	0.00	0.00	0.0%
8	1.11	Y	0.74	15.80	0.09	0.4%
9	1.03	T	191.90	4.26	12.36	91.9%
10	1.01	X	61.57	6.32	0.25	74.6%

VDD with C = 155 kip-sec/in

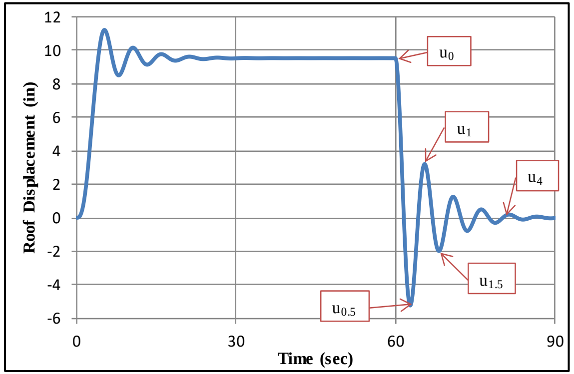
Analytical Studies of VDD Linear Damping



Method 1
Modal Properties



Method 2
Dissipated Energy in the System under Free Vibration



Method 3
Decay of Motion in Free Vibration

VDD Linear Damping		
Target	**C (kip-in/sec)**	**Damping Ratio**
Method 1	155	11.2%
Method 2	155	10.9%
Method 3	155	15.6%

VDD Linear Damping		
Lower Bound	C (kip-in/sec)	Damping Ratio
Method 1	131.75	9.6%
Method 2	131.75	9.8%
Method 3	131.75	13.5%

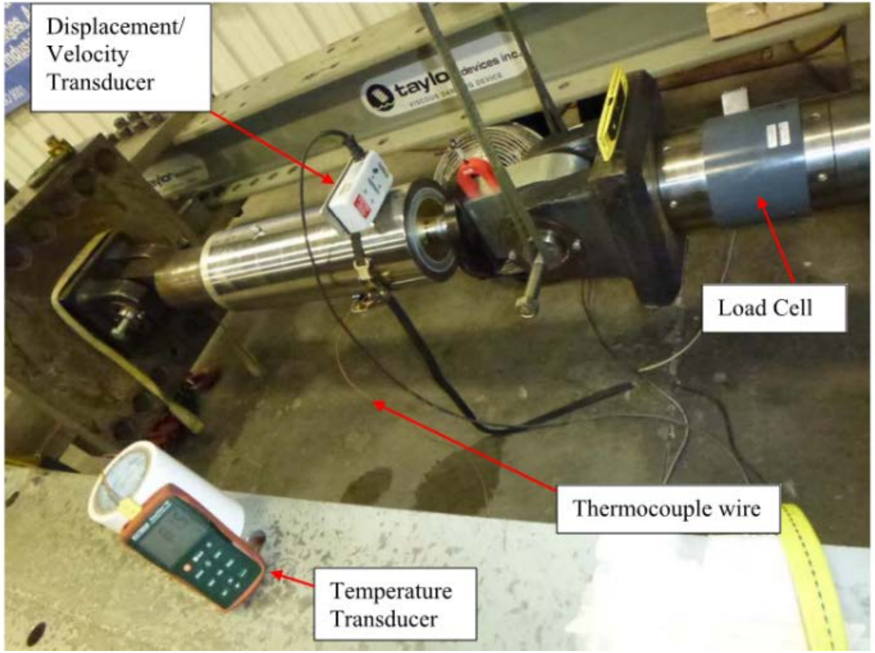
(Ref. Dynamics of Structures, A.K. Chopra)

PROTOTYPE DAMPER TESTING

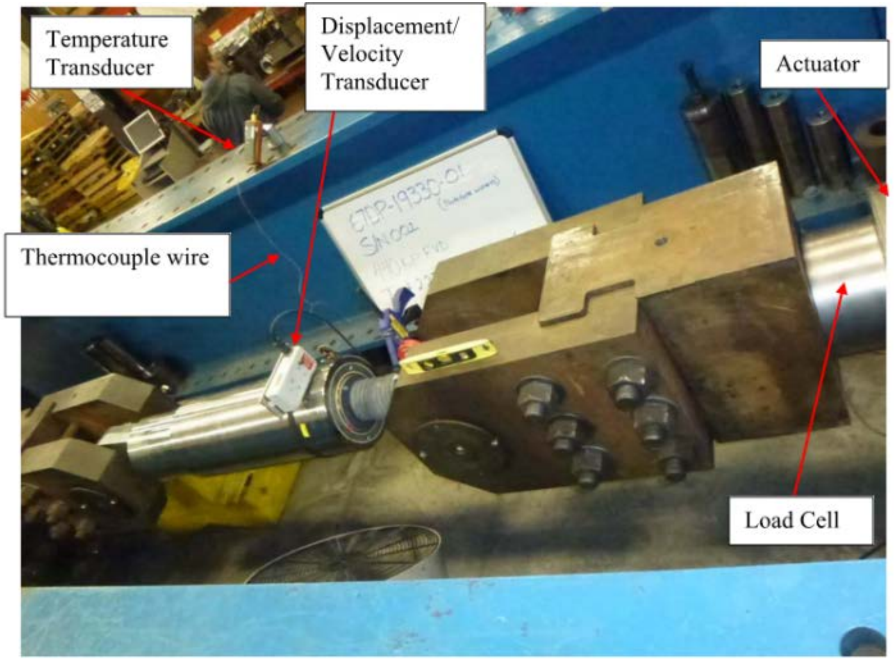
SOM

Prototype Damper Testing

(Taylor Devices, Inc., Jan. 2015)



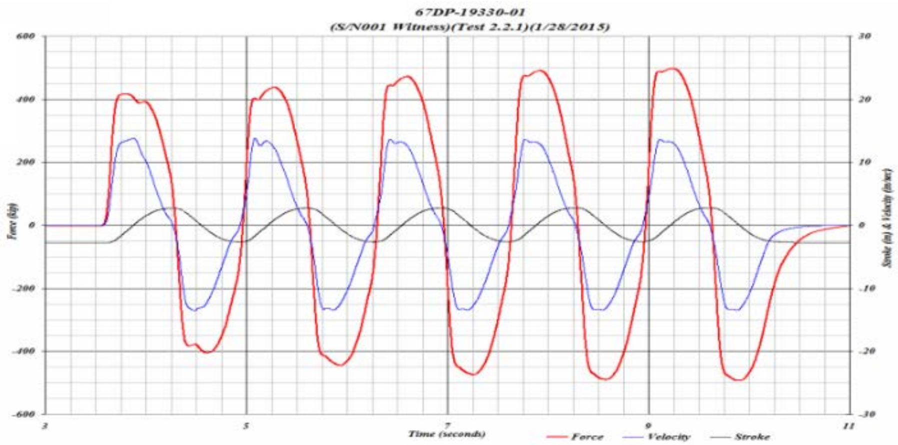
View of 330kip SN001 Damper in Small Tester

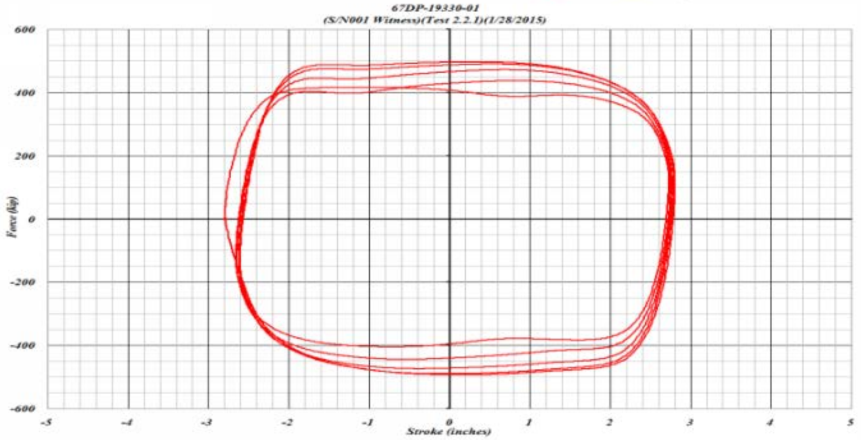


View of 440kip SN001 Damper in Large Tester

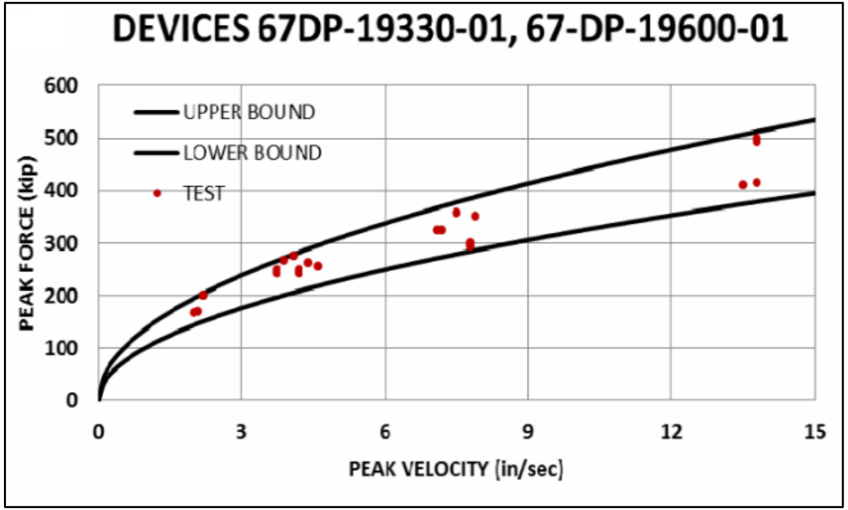
Ref: M. Constantinou Report (2/3/2015)

Prototype Damper Testing (440kip)



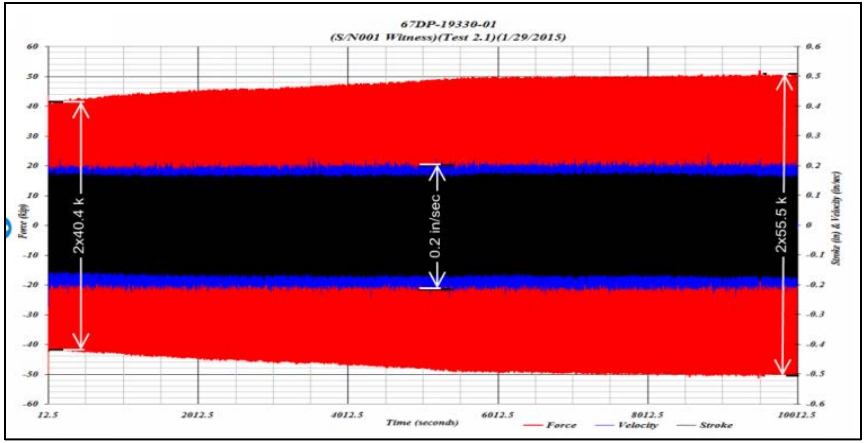


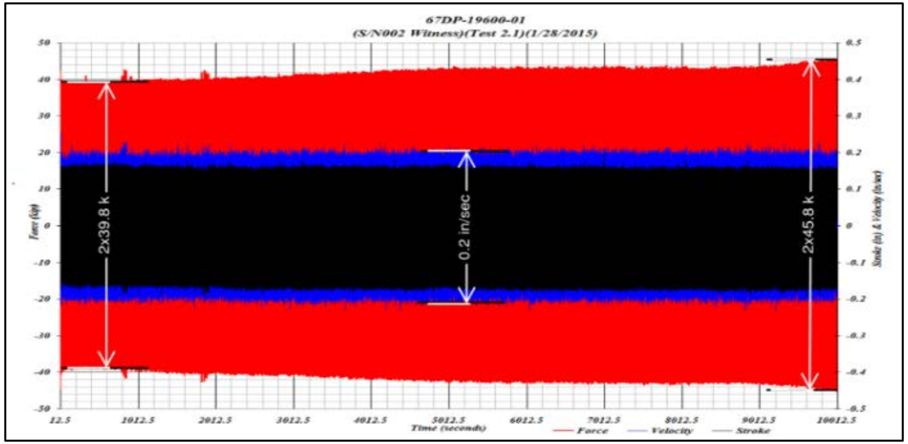
Seismic (5 cycles, +/- 2.85 in, 13.5 in/sec)

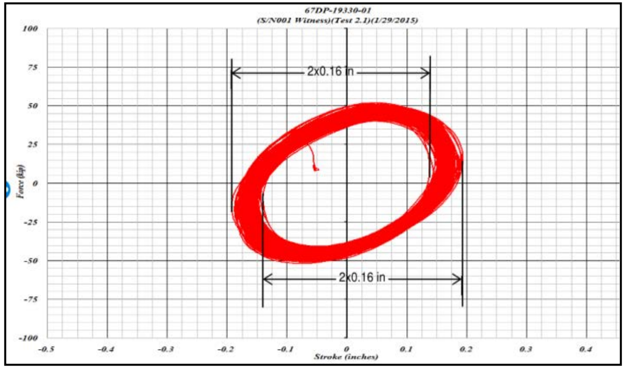


Velocity Performance Test Results

Wind Cyclic Testing (440kip & 330kip)



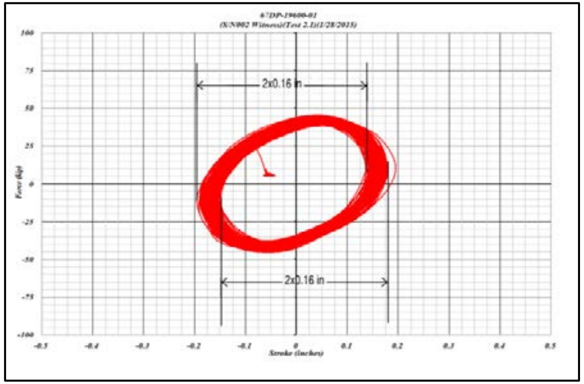




2000 cycles (ASCE 7)

Displacement = +/- 0.17 in

Velocity = 0.2 in/sec



440 kip damper

330 kip damper

Viscous Damping Device Analytical and Test Results

Comparison	Damping Constant, C (kip in/sec)	Damping Ratio
Analytical Studies		
Method 1	155	11.2%
Method 2	155	10.9%
Method 3	155	15.6%
Prototype Testing		
330 kip	195-229	14.1-16.5%
440 kip	199-277	14.4-20.0%

SPECIAL MOMENT FRAME QUALIFICATION TESTING

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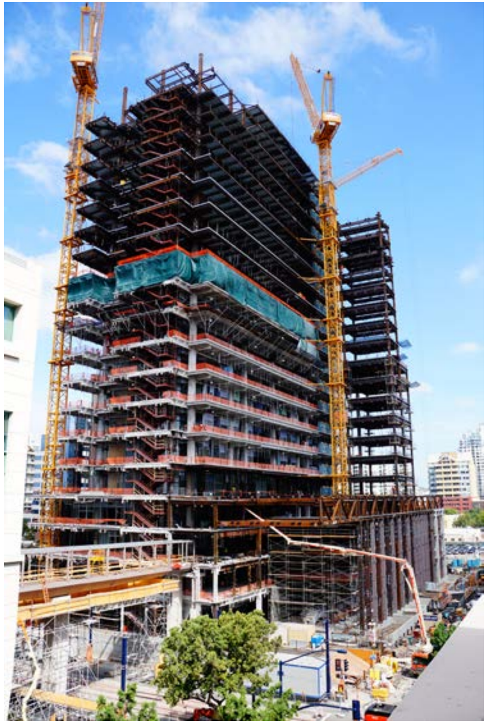
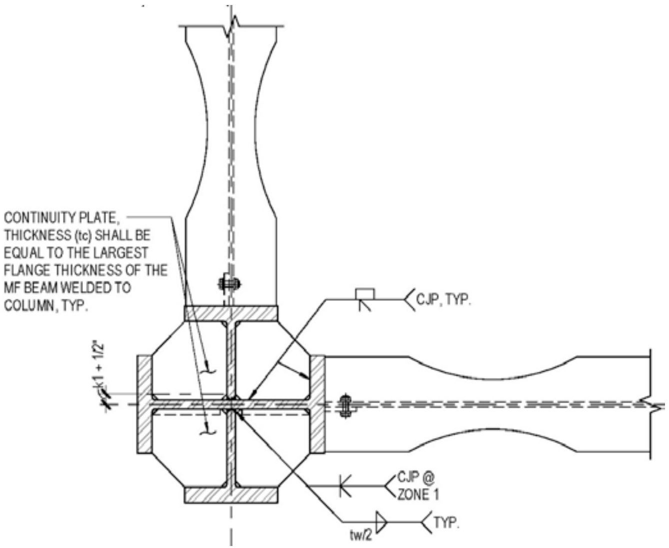
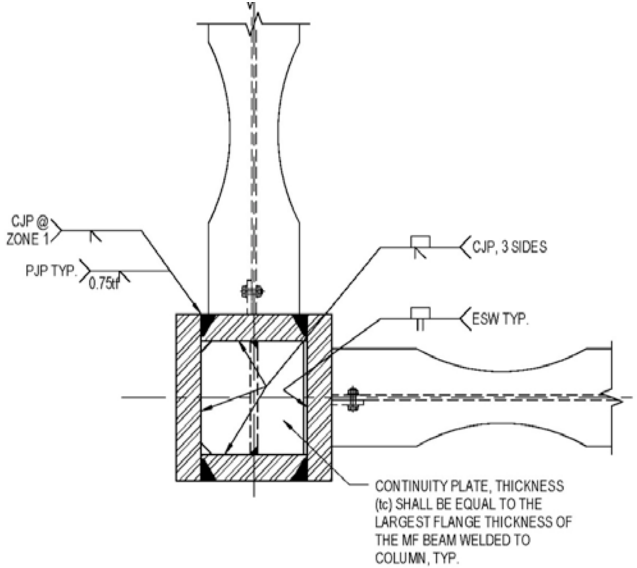
Full-Scale Testing Background – SDCC Project



Courthouse under construction (2015)



2-W30 Cruciform (max)
(Prequalified per AISC)



Square Box 33x33 (max)
Rectangular Box 24x36 (max)
Testing required per AISC 341 & 358
(> 24 inch)

SAN DIEGO CENTRAL COURTHOUSE
SKIDMORE, OWINGS & MERRILL LLP

Full-scale Testing Program

Box Column
24"x36"x2"

W36x302
RBS Beam

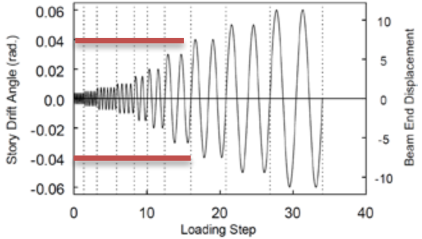
SAN DIEGO CENTRAL COURTHOUSE
SKIDMORE, OWINGS & MERRILL LLP

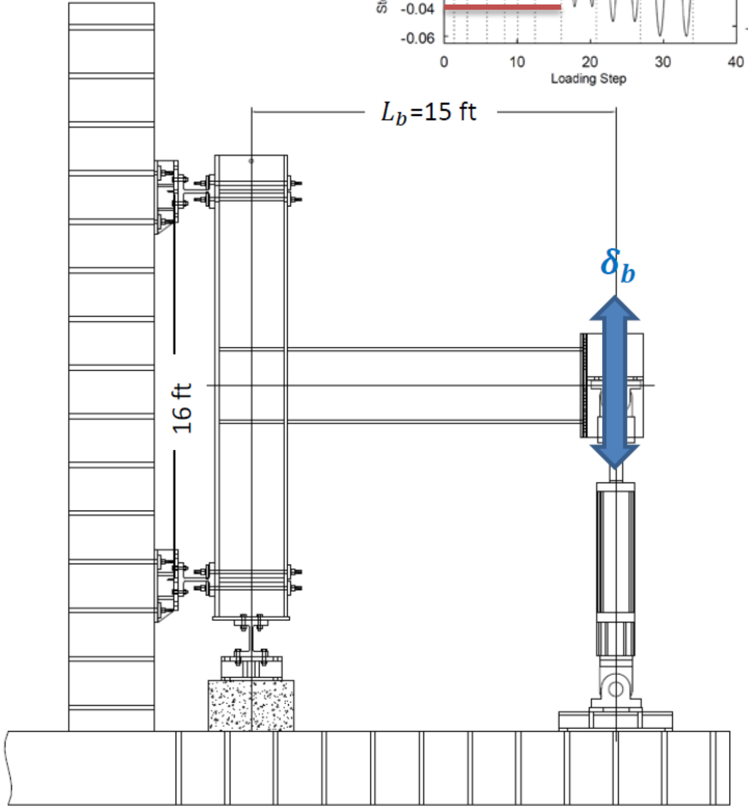
Column (A572 Gr.50):
RHS 36x24x2
d = 36"
t_w = 2"
h/t_w = 16
b_f = 24
t_f = 2
b_f/t_f = 10

Beam Size (A992 Gr.50):
W36X302
d = 37.3"
t_w = 0.95"
h/t_w = 33.9
b_f = 16.7
t_f = 1.68
$b_f/2t_f$ = 4.96

Continuity Plate (A572 Gr.50):
Plate 32x20x1.75

$\delta_b = L_b \times \text{Story drift angle}$





(G. Ozkula, C.M. Uang / UCSD)

In-closing,

Thank you.

Acknowledge the following SOM structural engineers … that I have been fortunate enough to work with in contributing to solve the challenging aspects of this project.

Rupa Garai

Alvin Tsui

Lachezar Handzhiyski

Chung-Soo Doo

In-closing,

Thank you.

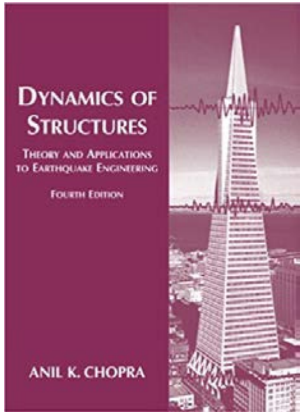
Acknowledge the following SOM structural engineers … that I have been fortunate enough to work with in contributing to solve the challenging aspects of this project.

Rupa Garai

Alvin Tsui

Lachezar Handzhiyski

Chung-Soo Doo



SAN DIEGO CENTRAL COURTHOUSE
SKIDMORE, OWINGS & MERRILL LLP

THE ROLE OF STRUCTURAL ENGINEERING EDUCATION
TWO PRACTITIONER PERSPECTIVES

PETER LEE AND NEVILLE MATHIAS

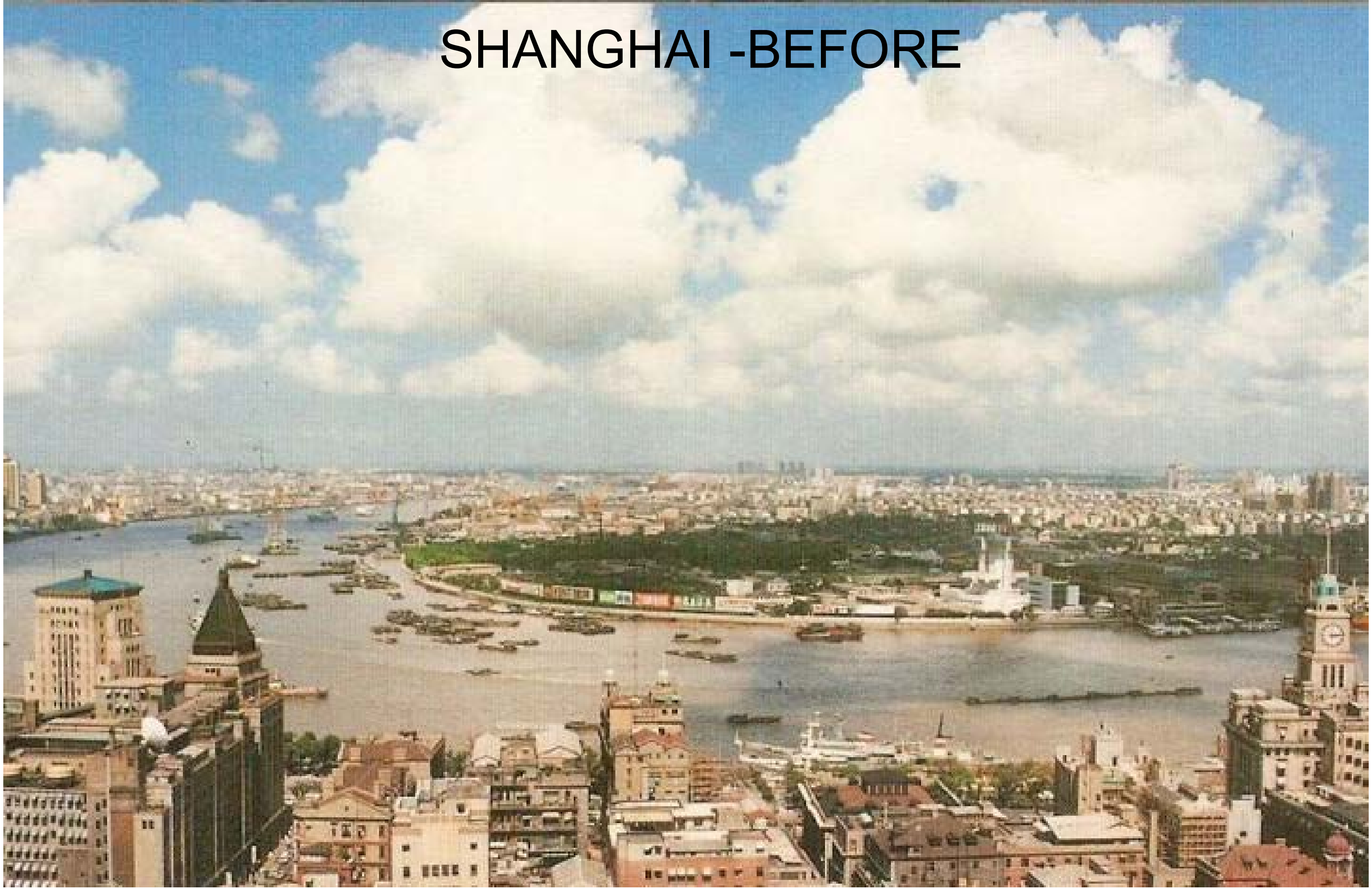
Retirement Symposium and Celebration
For Professor Chopra
03 October 2017

SOM

Bechtel Engineering Center, Sibley Auditorium
University of California, Berkeley

WITNESS TO CHANGE

SHANGHAI -BEFORE



SHANGHAI -AFTER

China's Building Blitz

In scale and pace, the building boom currently sweeping over China has no precedent in human history. China is spending about $375 billion each year on construction, nearly 16 percent of its gross domestic product. In the process, it is using 54.7 percent of the world's production of concrete, 36.1 percent of the world's steel, and 30.4 percent of the world's coal.

ICBC-BEIJING

JINMAO BUILDING-SHANGHAI

EXPERT PANEL REVIEW (EPR)

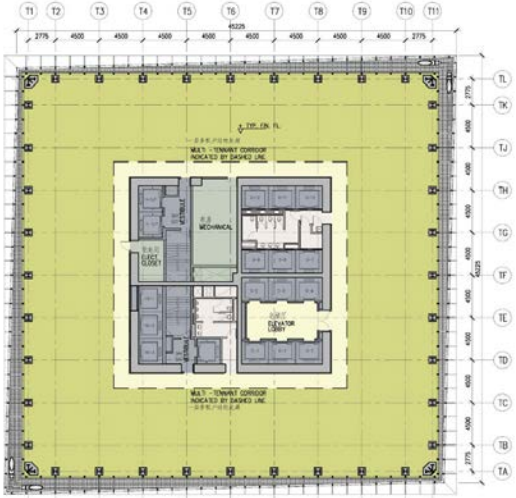
- Process For Assuring Desired Performance of Code Exceeding (Non-Prescriptive) Building Structures

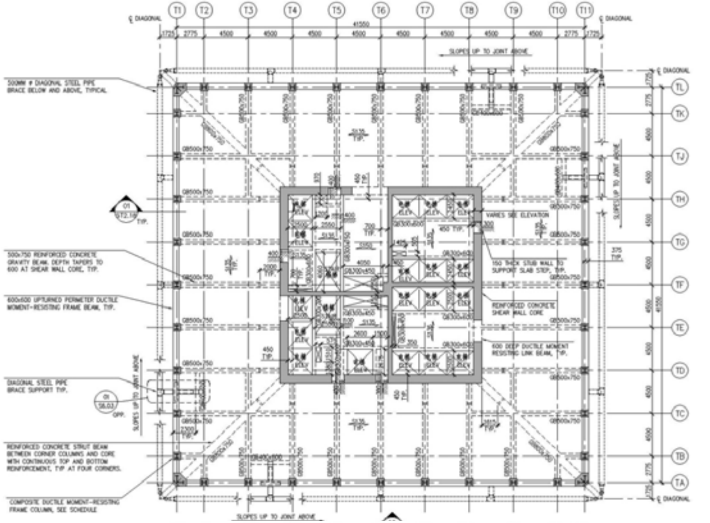
EPR APPROACH

- Performance Assurance in EPR is based on principles of Capacity Design and an Intuitive / First Principle understanding of structural behavior.
- At a Global Level, structural performance is tied to Inter-Story Drift. Damage is controlled by Limiting Drifts at Three Hazard Levels.
- At a Component Level, performance is ensured by providing enhanced strength performance of Key Components at Three Hazard Levels.

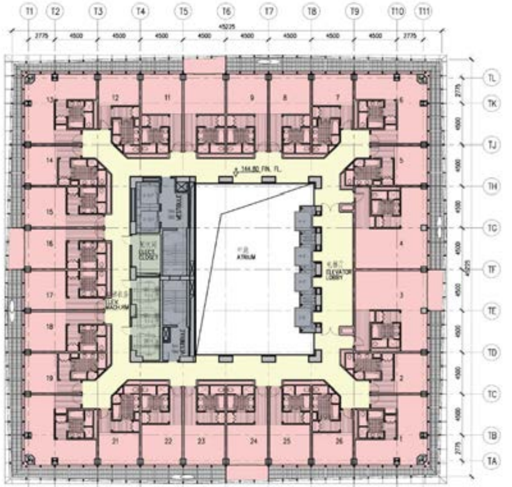
JINAO TOWER-NANJING

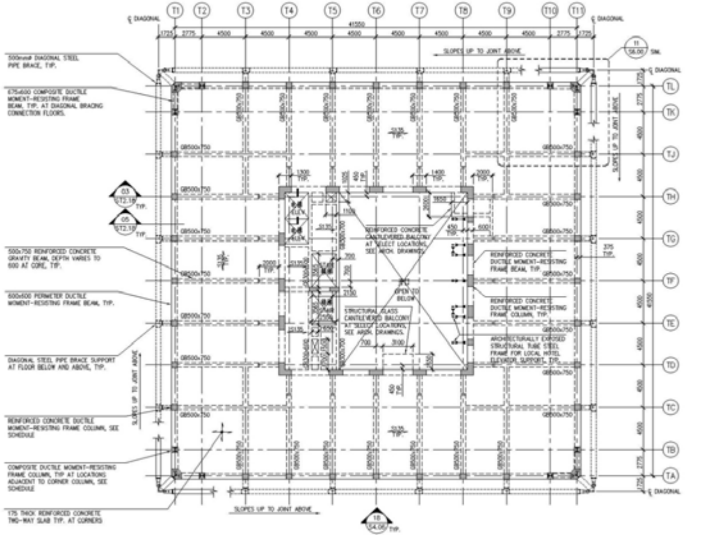
OFFICE FLOOR

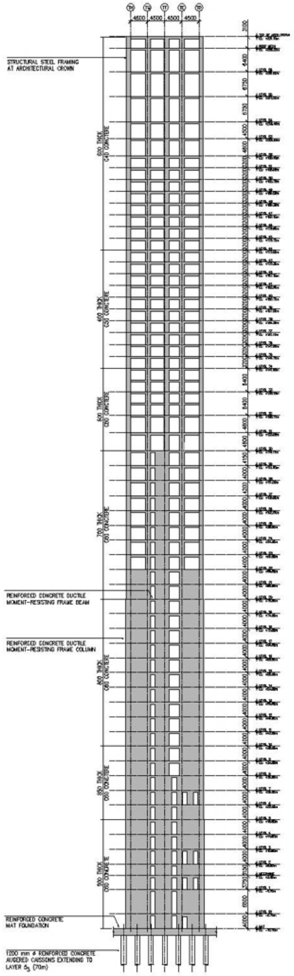


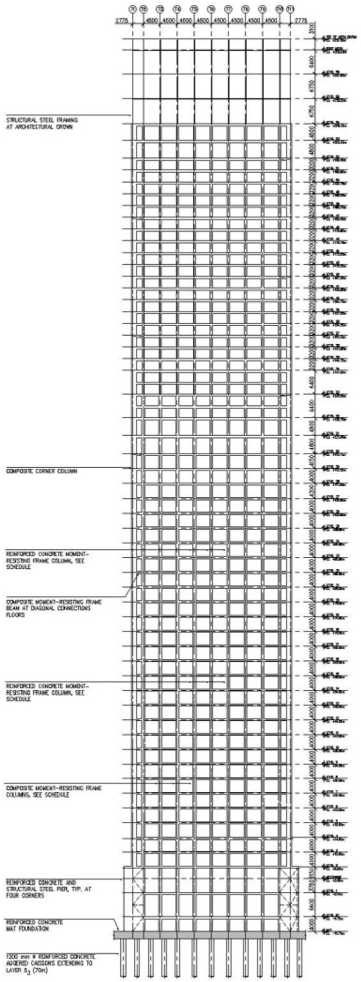


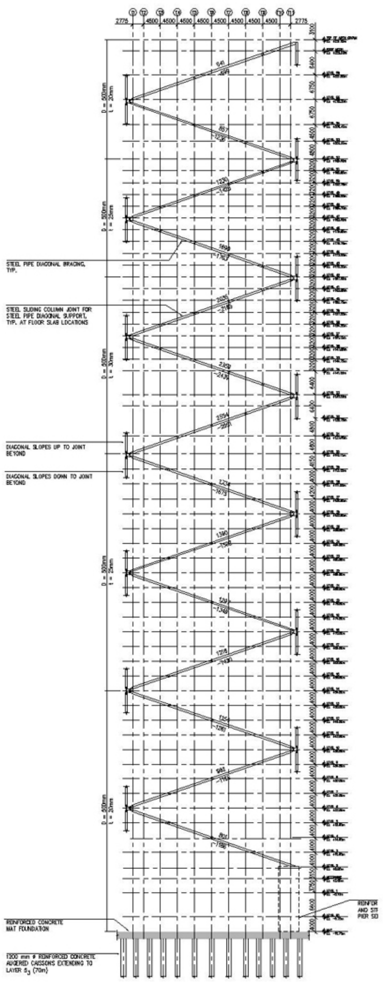
HOTEL FLOOR



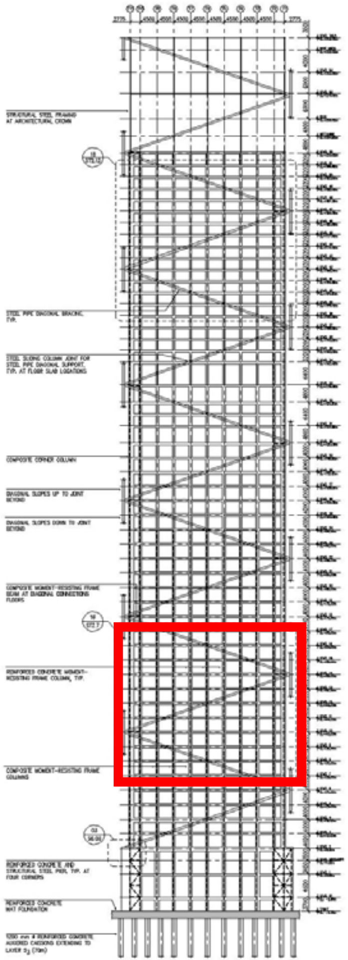


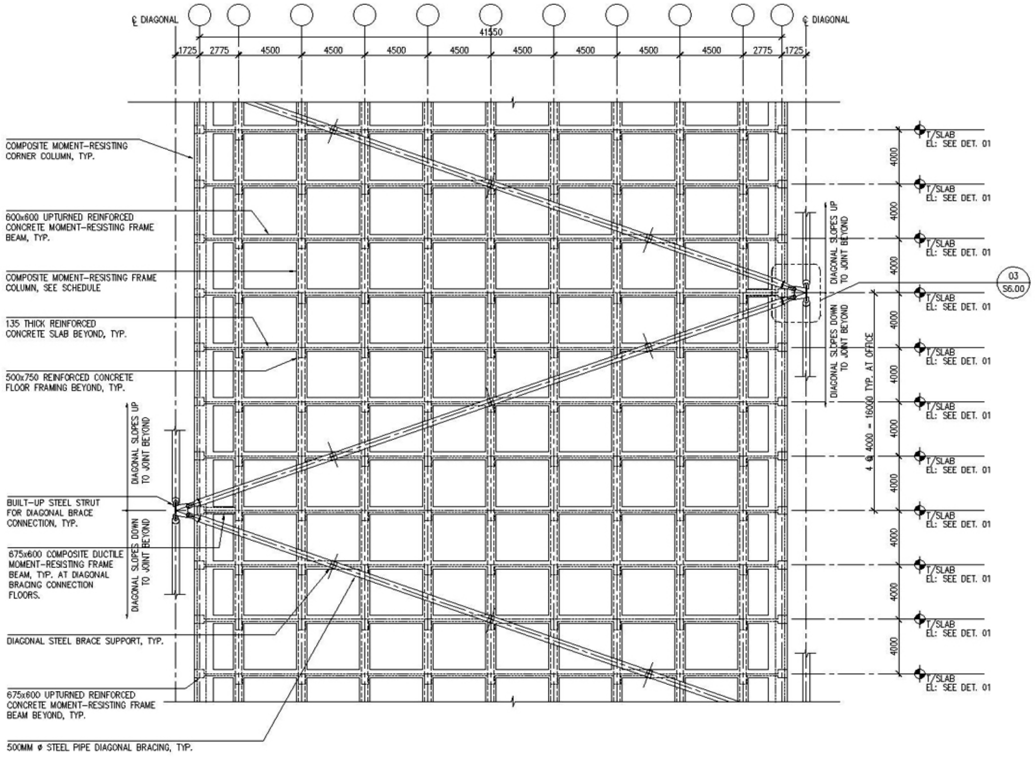




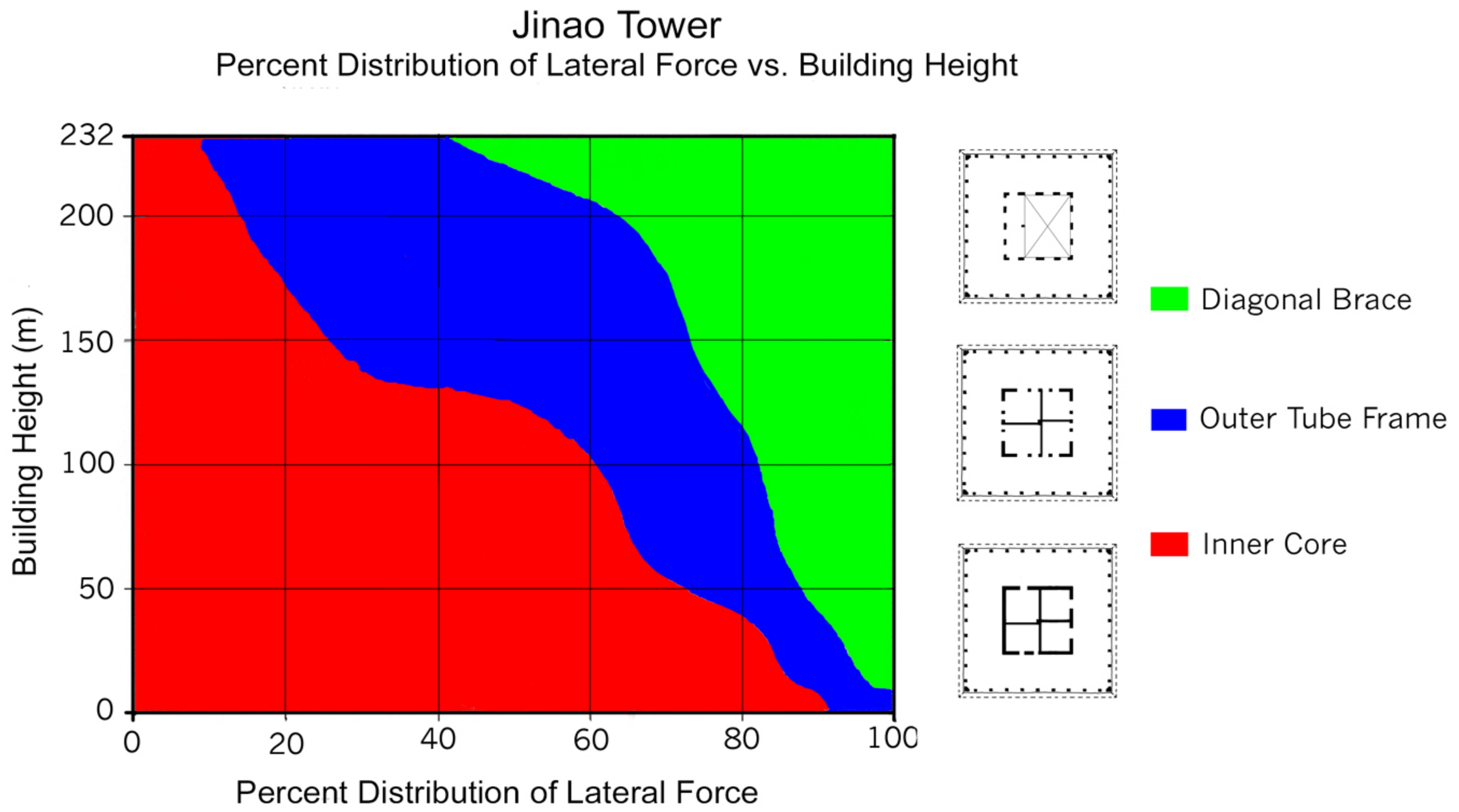


TYPICAL TOWER TUBE FRAME ELEVATIONS



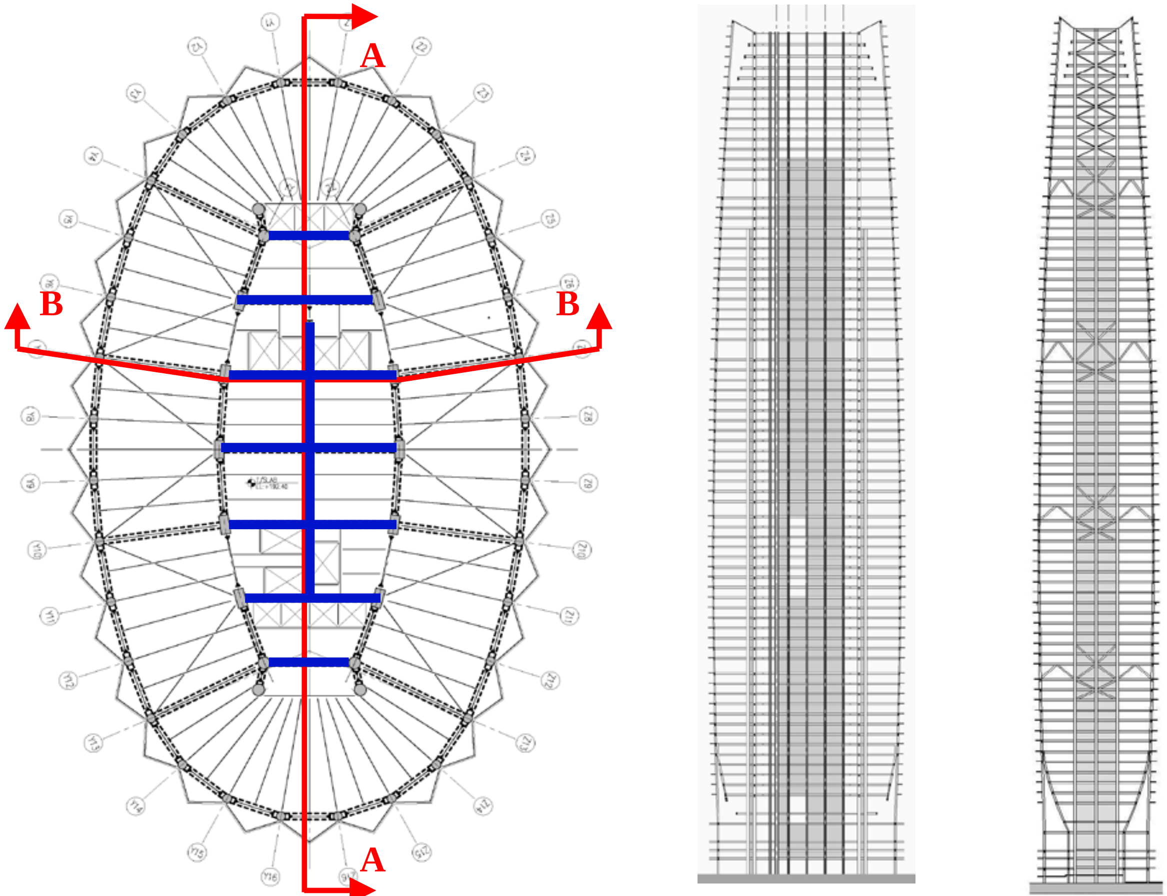


TYPICAL BRACED TUBE FRAME ELEVATION

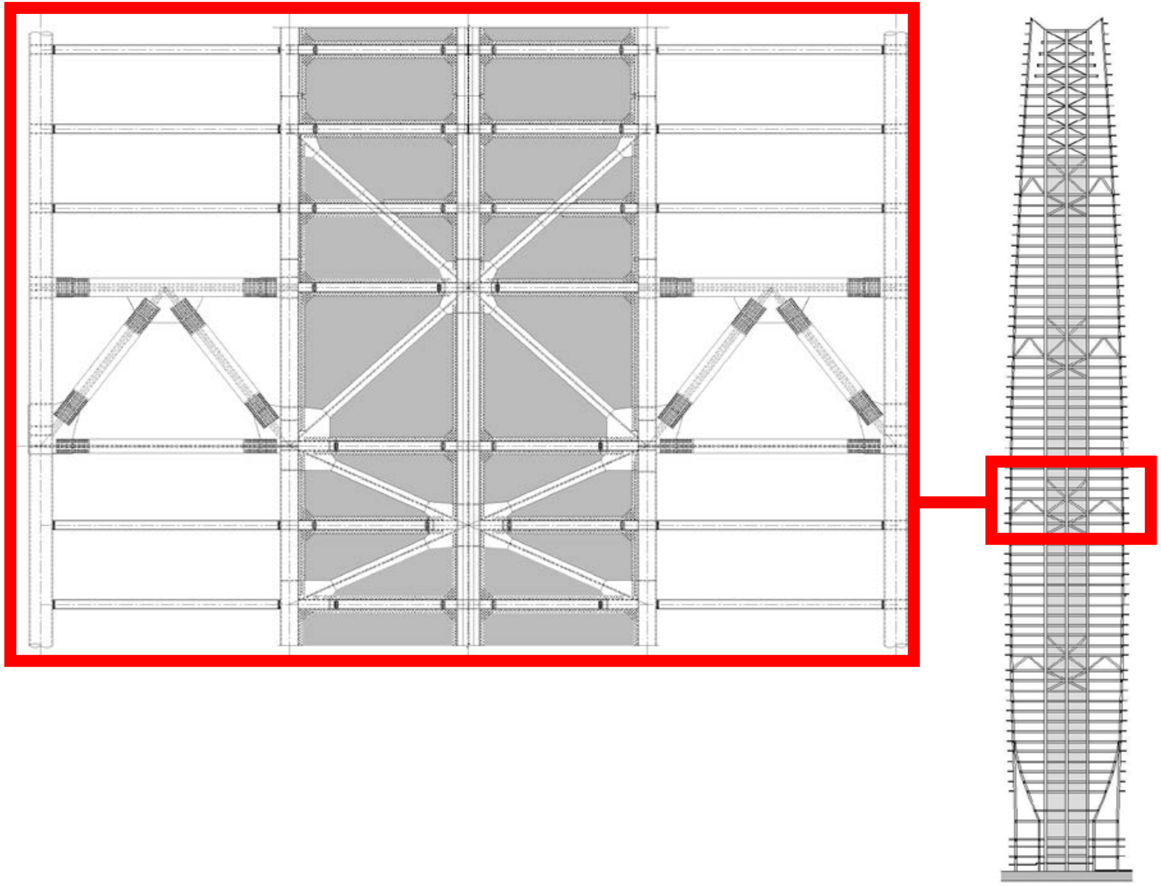


Jinao Tower
Percent Distribution of Lateral Force vs. Building Height
Building Height (m)
232
200
150
100
50
0
0
20
40
60
80
100
Percent Distribution of Lateral Force
Diagonal Brace
Outer Tube Frame
Inner Core

JINTA TOWER-TIANJIN

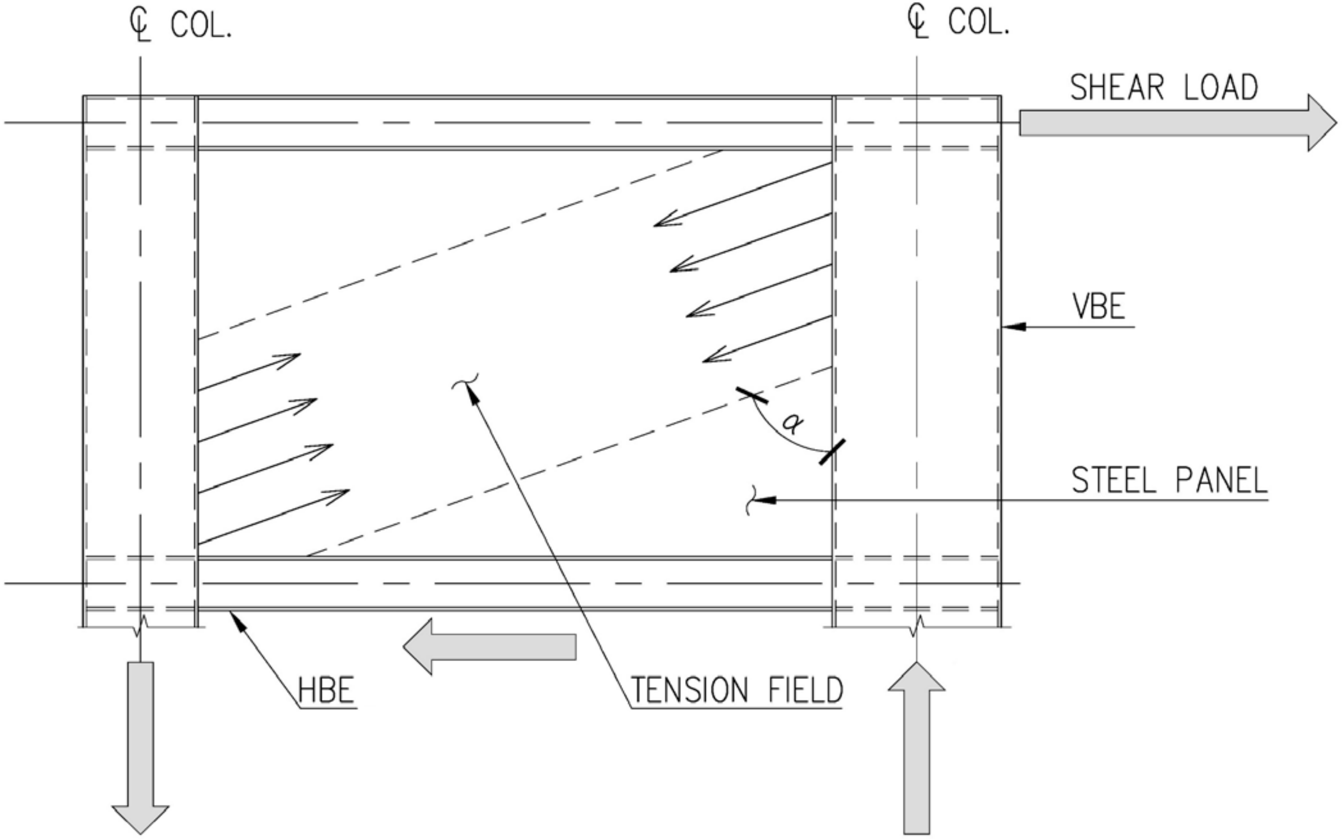
SOM



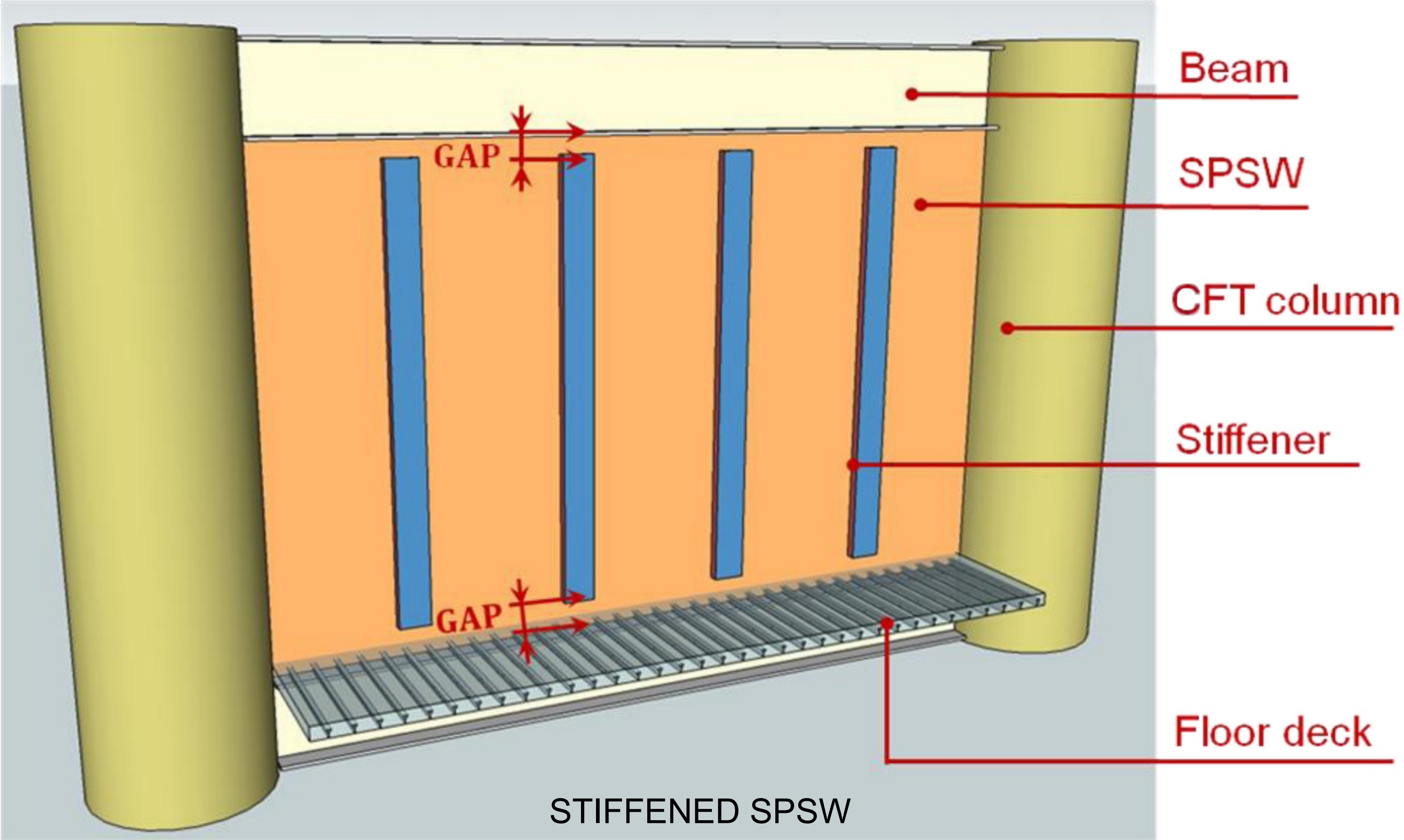
TYPICAL FRAMING PLAN AND SECTIONS



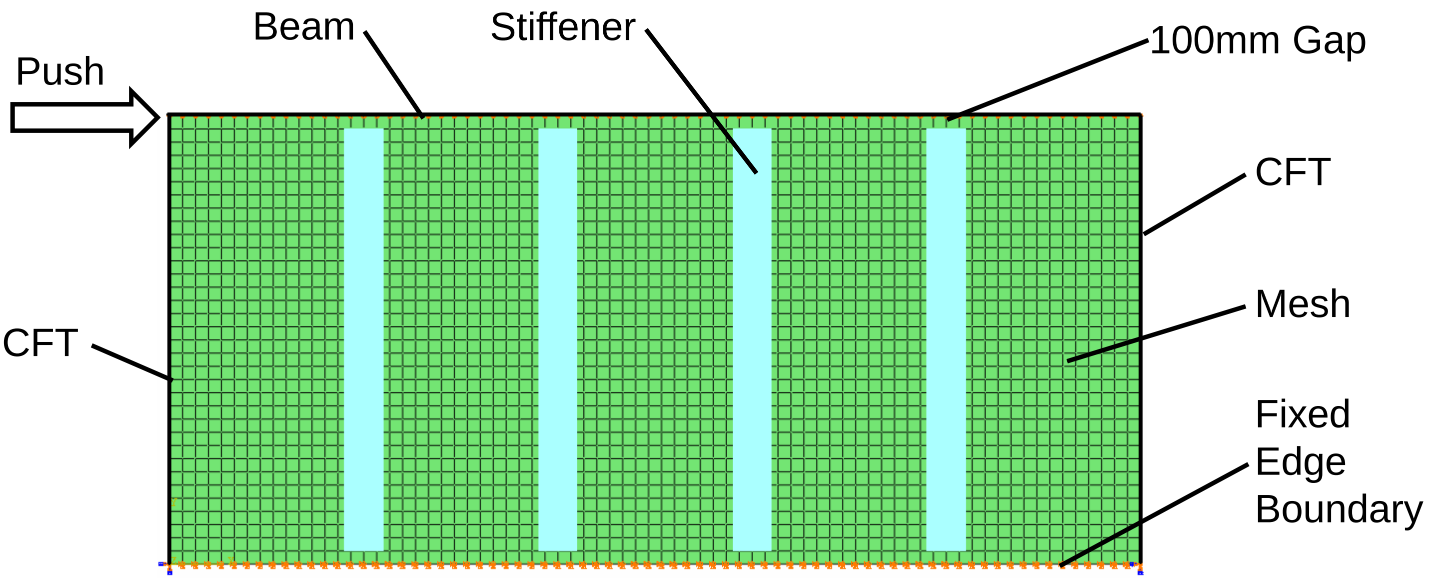
OUTRIGGER ELEVATION



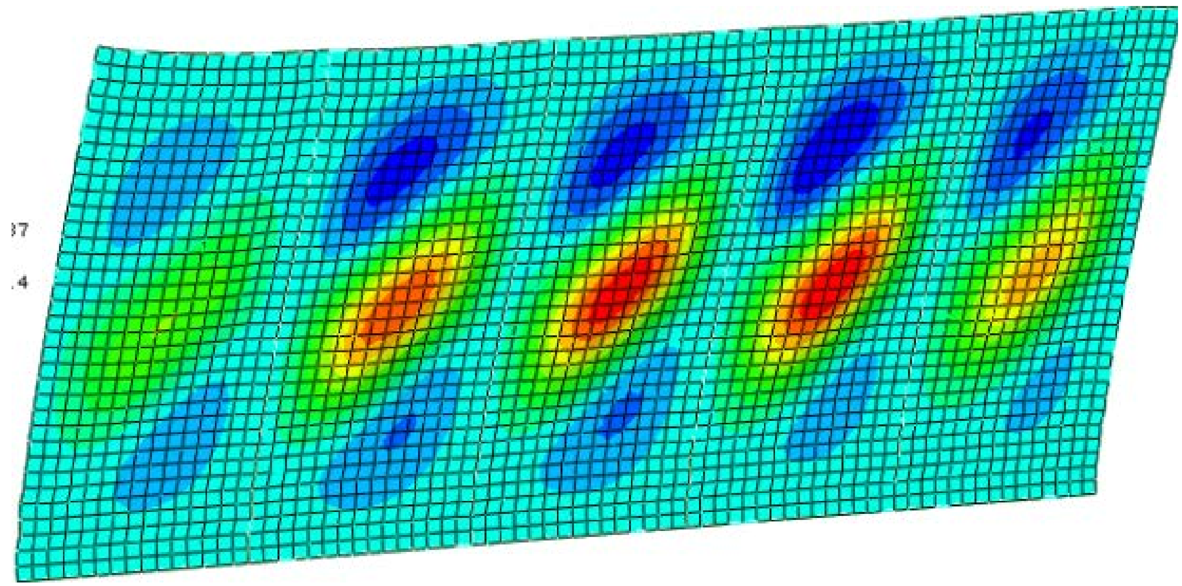
SLENDER SPSWS-TENSION FIELD ACTION



STIFFENED SPSW



STIFFENED SPSW

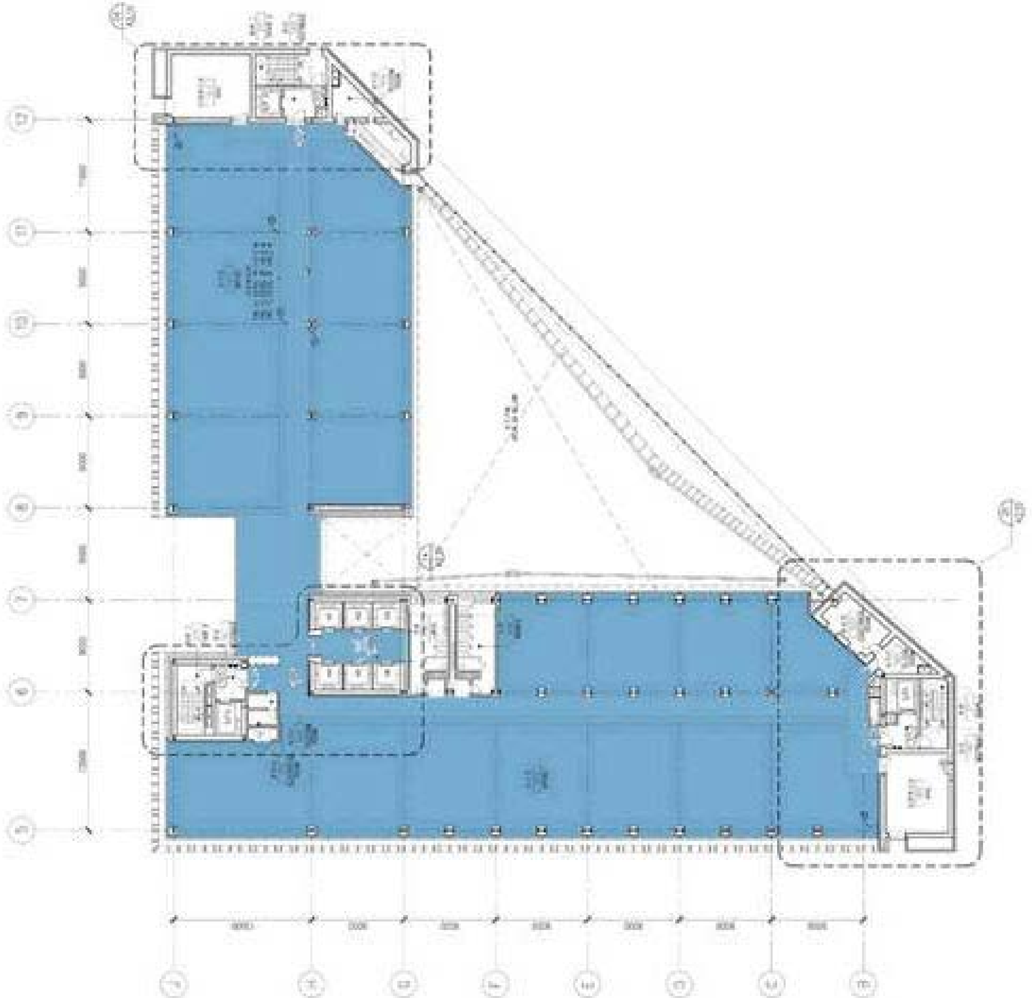


STIFFENED SPSW—PUSH OVER

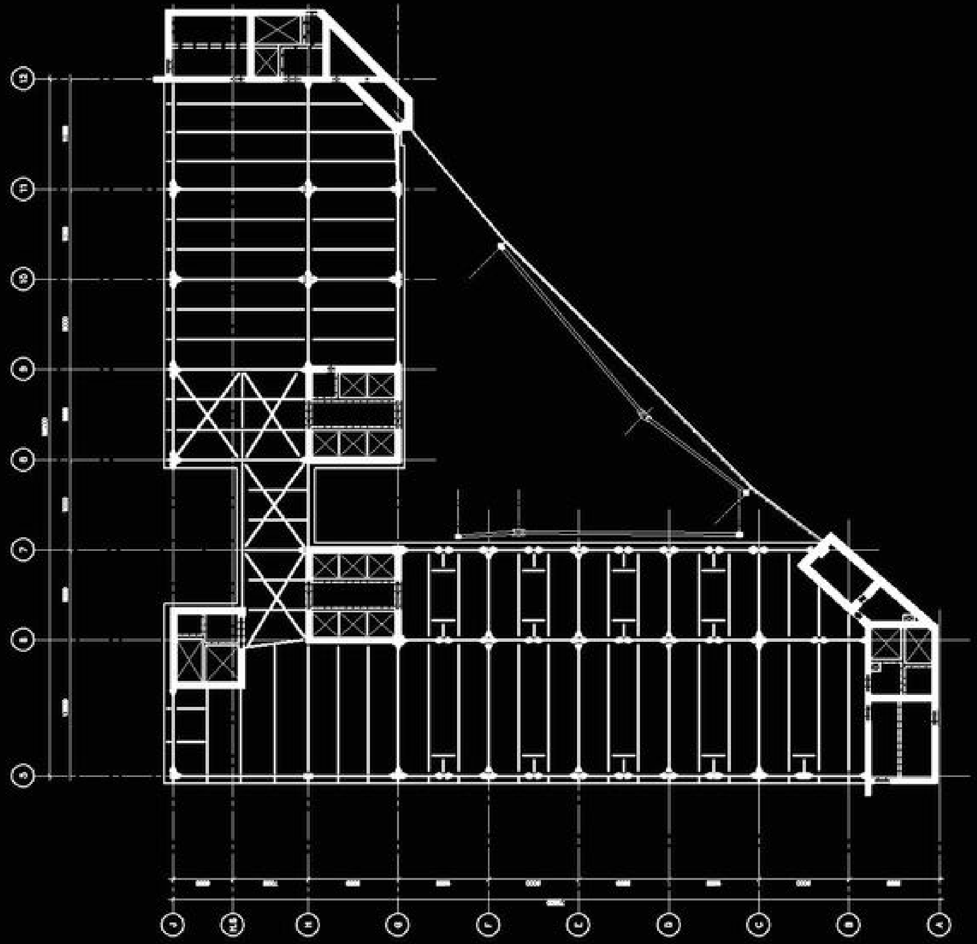
TEST MODEL

POLY BEIJING

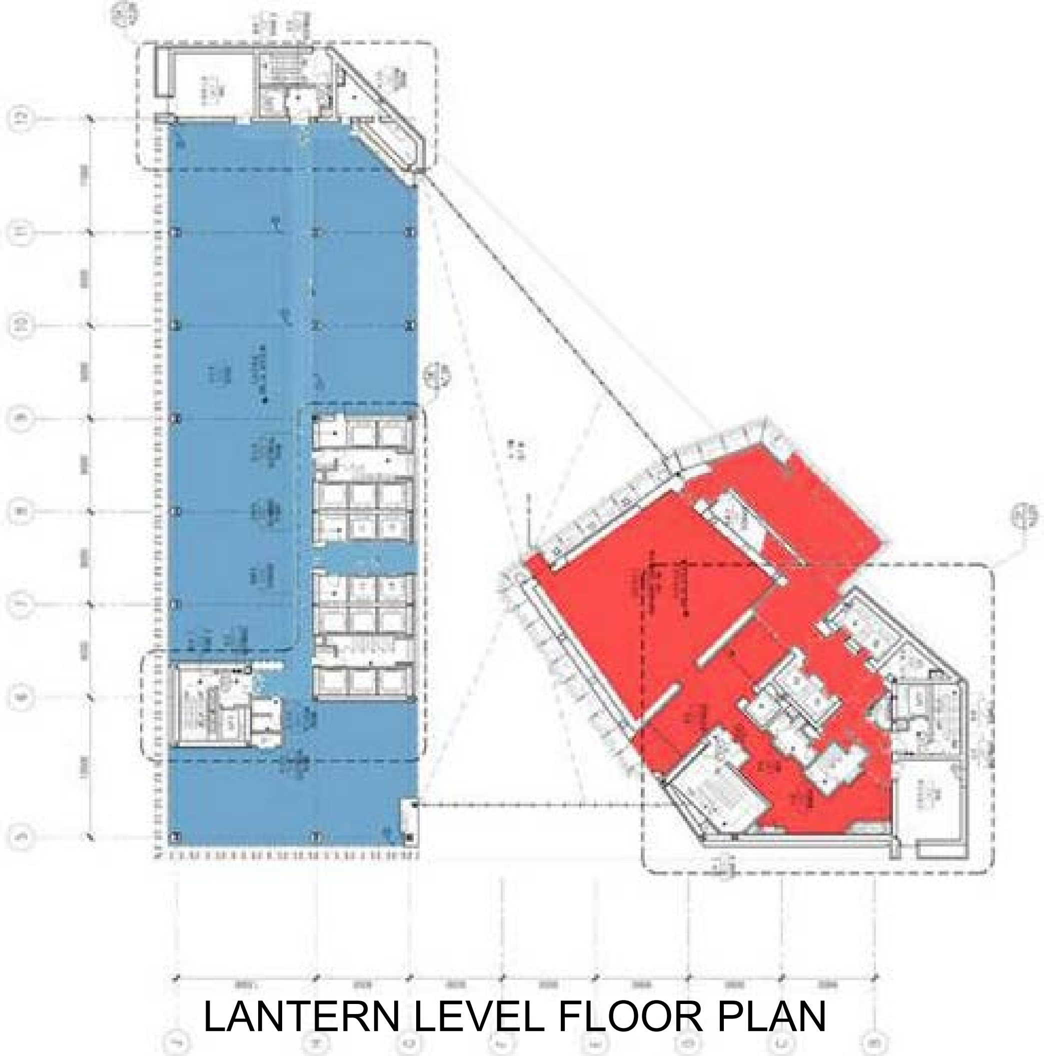
SOM



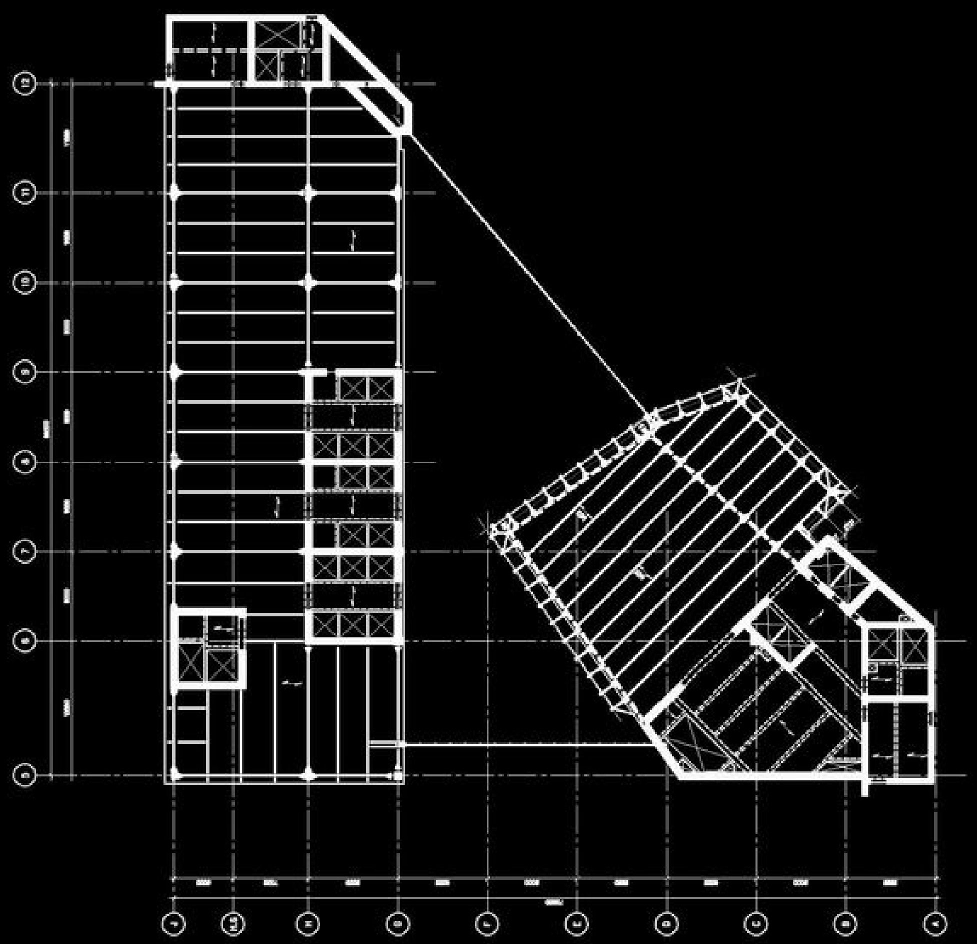
TYPICAL FLOOR PLAN



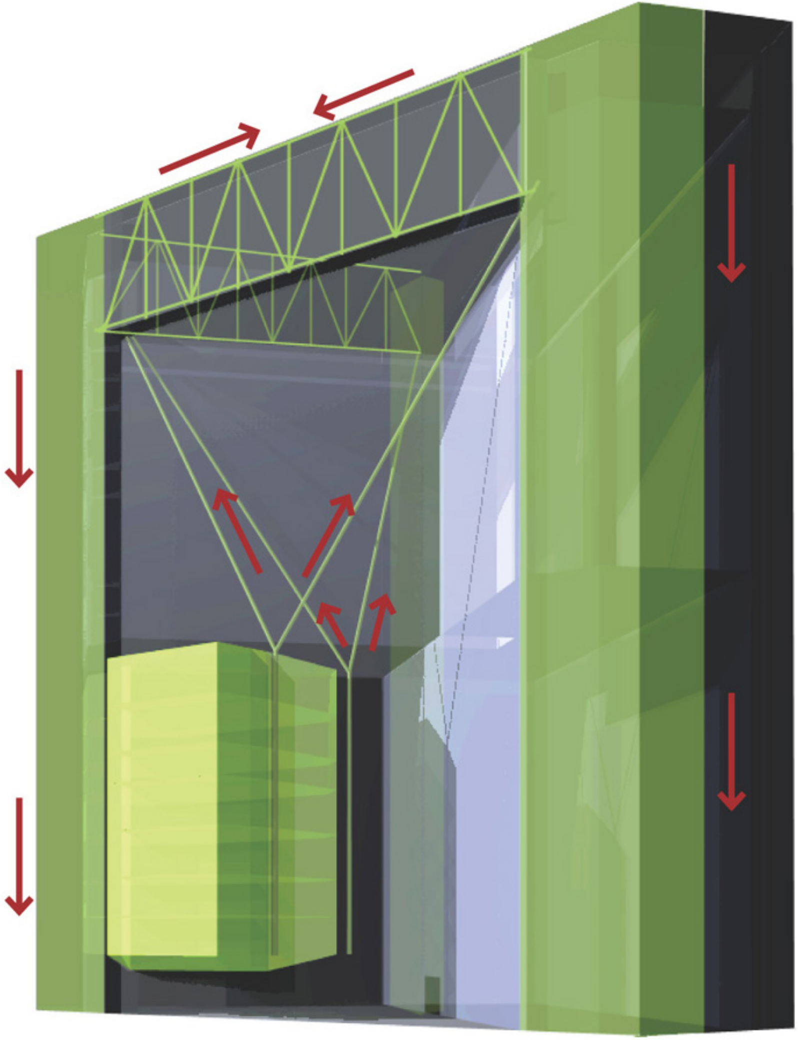
FLOOR FRAMING PLAN

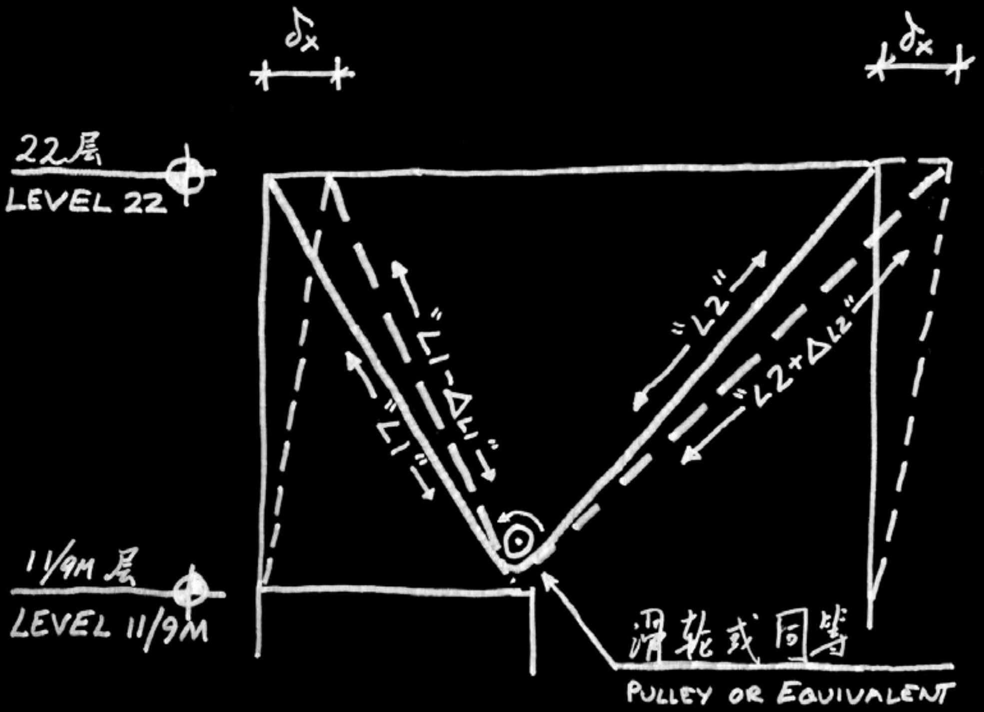


LANTERN LEVEL FLOOR PLAN



FLOOR FRAMING PLAN

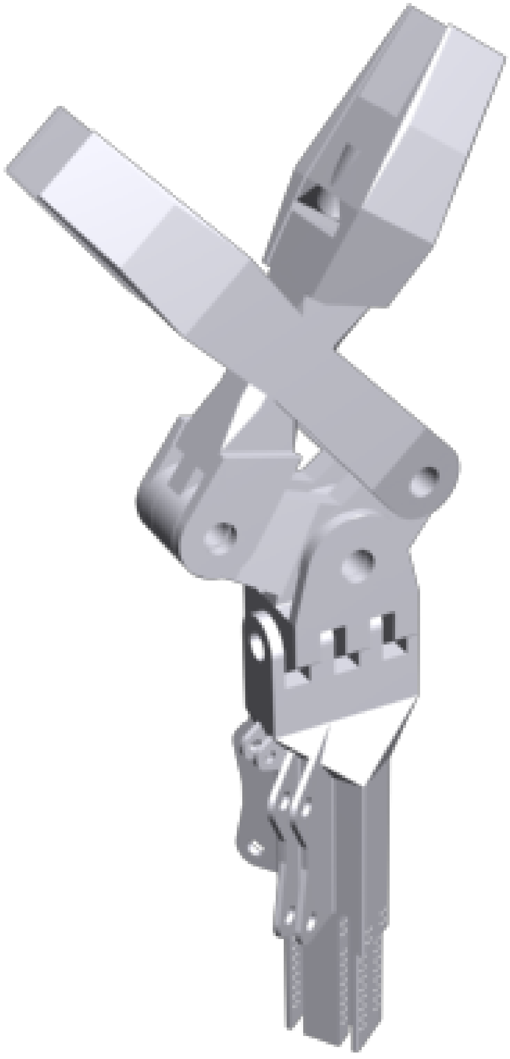


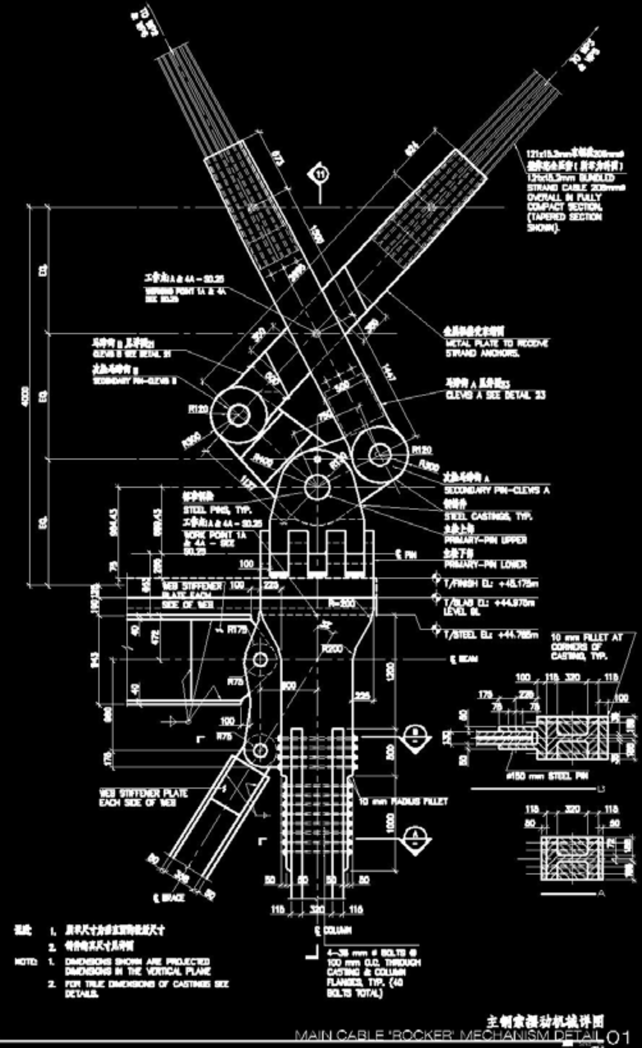


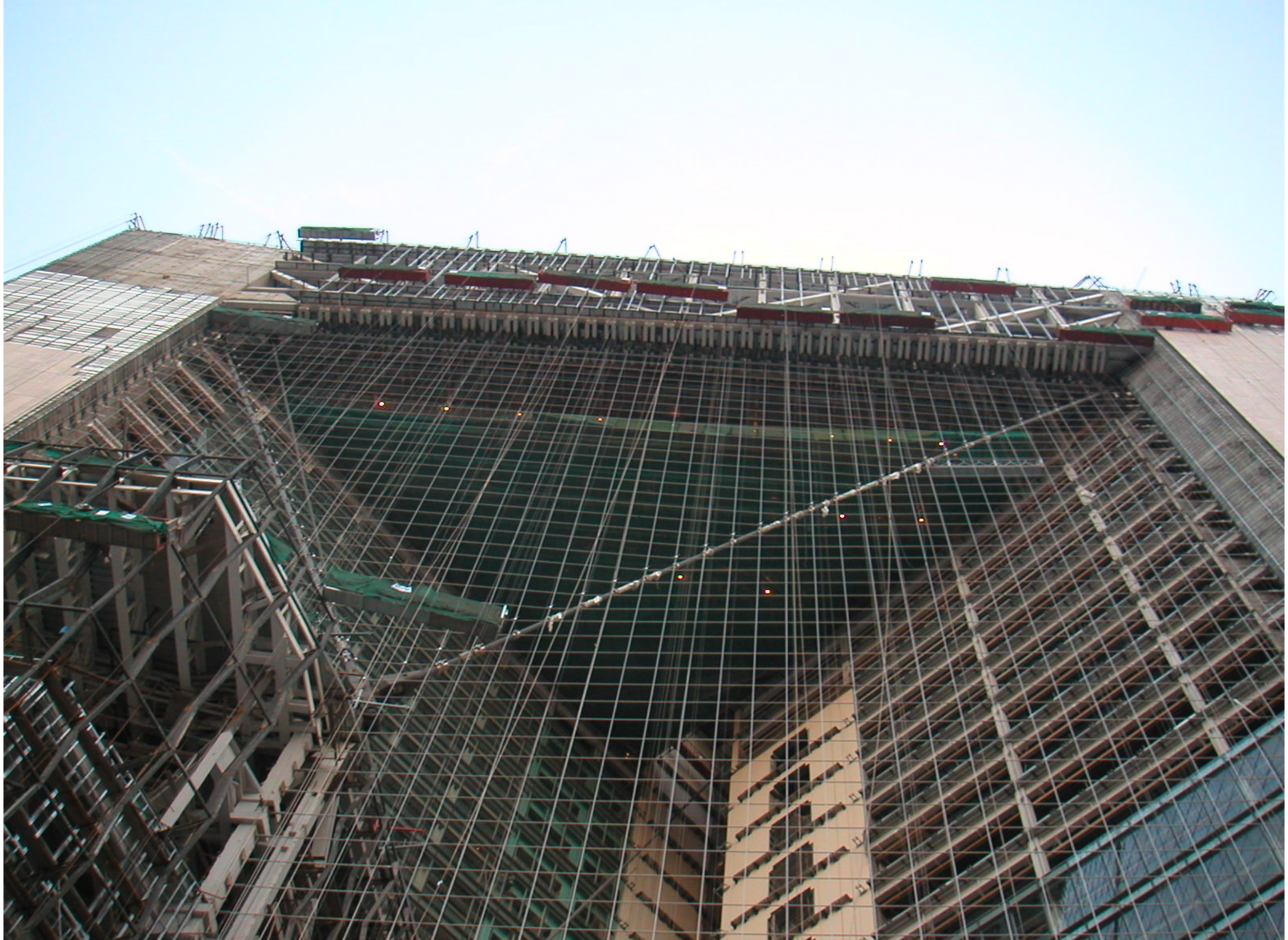
最终方案 — "V"底相似滑轮

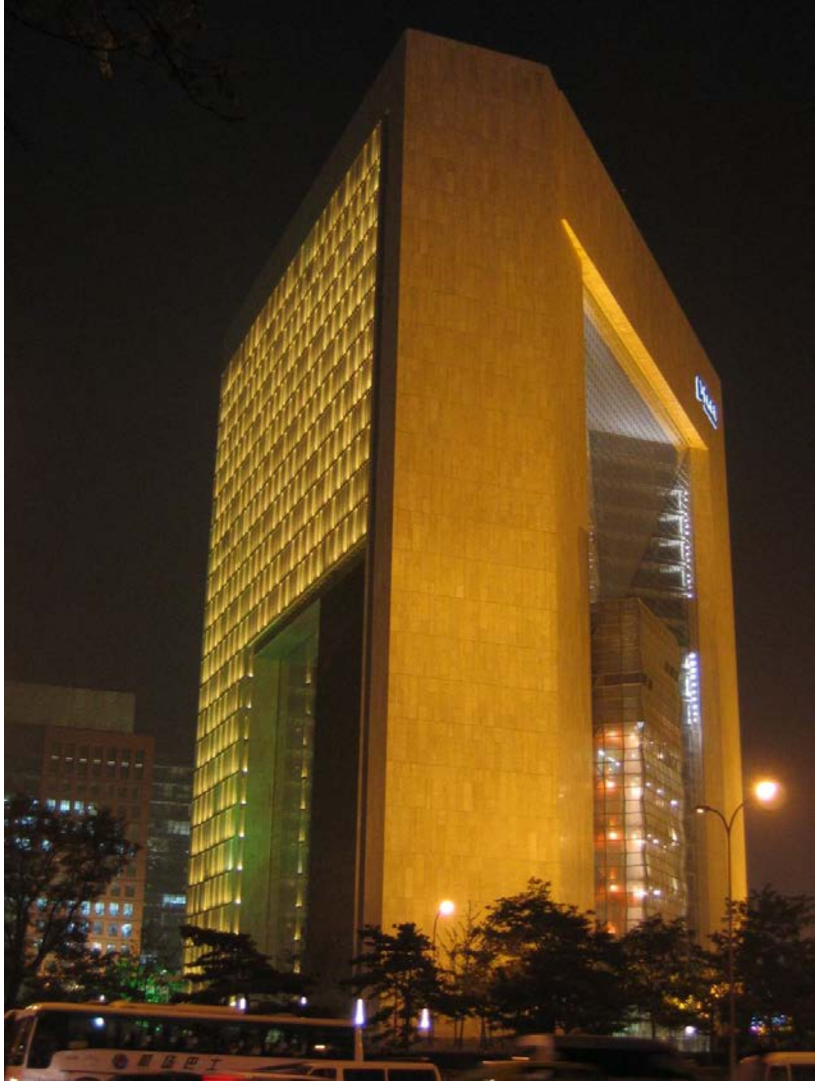
FINAL SCHEME – PULLEY EQUIVALENT AT BASE OF "V"

THE “ROCKER”




121x15.2mm BUNDLED STRAND CABLE 208mm⌀ OVERALL IN FULLY COMPACT SECTION. (TAPERED SECTION SHOWN).
METAL PLATE TO RECEIVE STRAND ANCHORS.
CLEVIS A SEE DETAIL 23
SECONDARY PIN-CLEVIS A
STEEL CASTINGS, TYP.
PRIMARY-PIN UPPER
PRIMARY-PIN LOWER
T/FINISH EL: +45.175m
T/SLAB EL: +44.975m LEVEL 9L
T/STEEL EL: +44.785m
10 mm FILLET AT CORNERS OF CASTING, TYP.
℄ BEAM
STEEL PINS, TYP.
WORK POINT 1A & 4A - SEE S0.25
SECONDARY PIN-CLEVIS B
WEB STIFFENER PLATE EACH SIDE OF WEB
10 mm RADIUS FILLET
⌀150 mm STEEL PIN
℄ BRACE
℄ COLUMN
4-36 mm ⌀ BOLTS @ 100 mm O.C. THROUGH CASTING & COLUMN FLANGES, TYP. (40 BOLTS TOTAL)
NOTE: 1. DIMENSIONS SHOWN ARE PROJECTED DIMENSIONS IN THE VERTICAL PLANE
2. FOR TRUE DIMENSIONS OF CASTINGS SEE DETAILS.
主钢索摆动机械详图
MAIN CABLE 'ROCKER' MECHANISM DETAIL 01



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