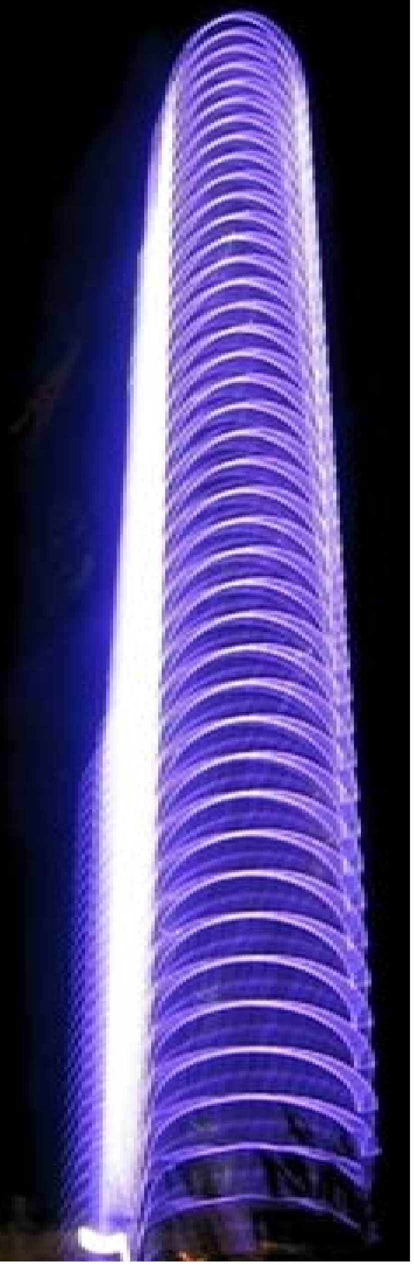
THE Borgata

ATLANTIC CITY



presented by

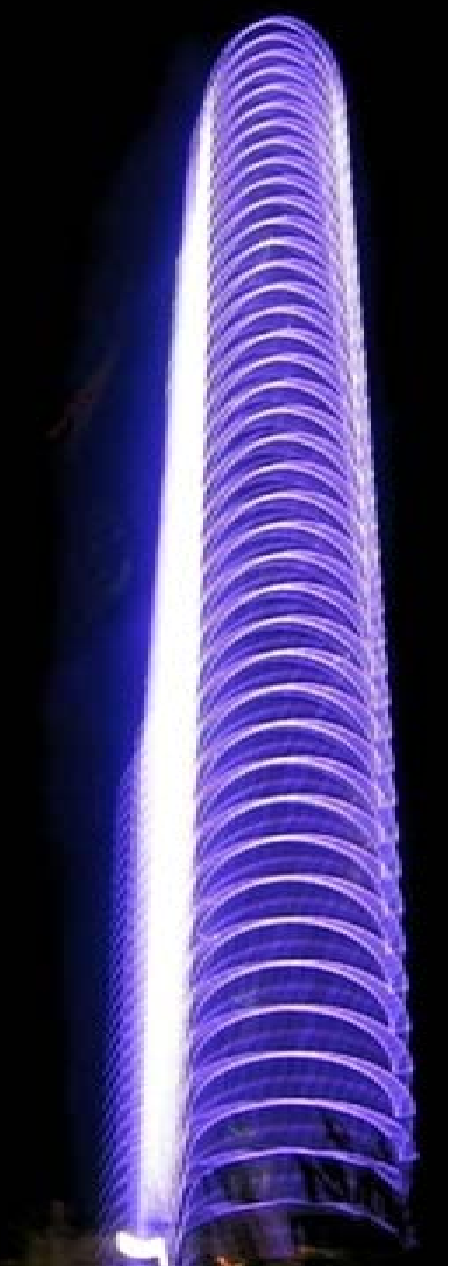
christopher m. shipper

structural option

advisor - dr. ali memari

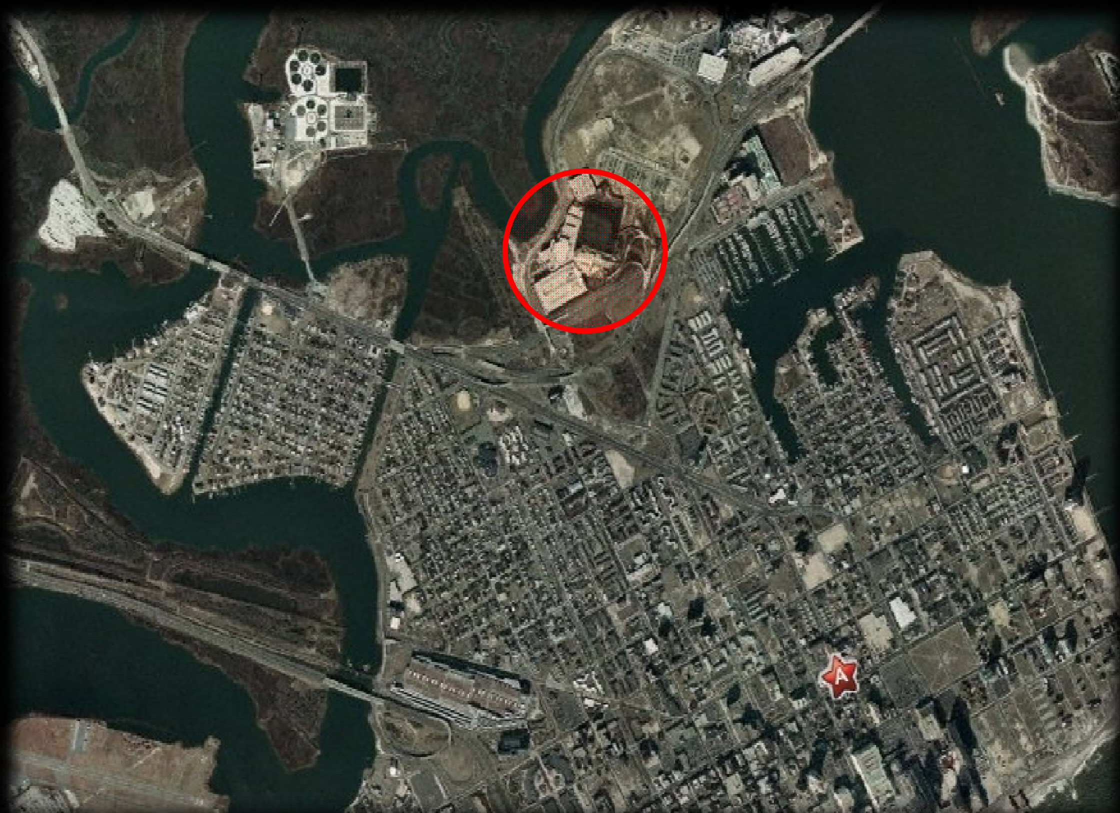
Presentation Topics

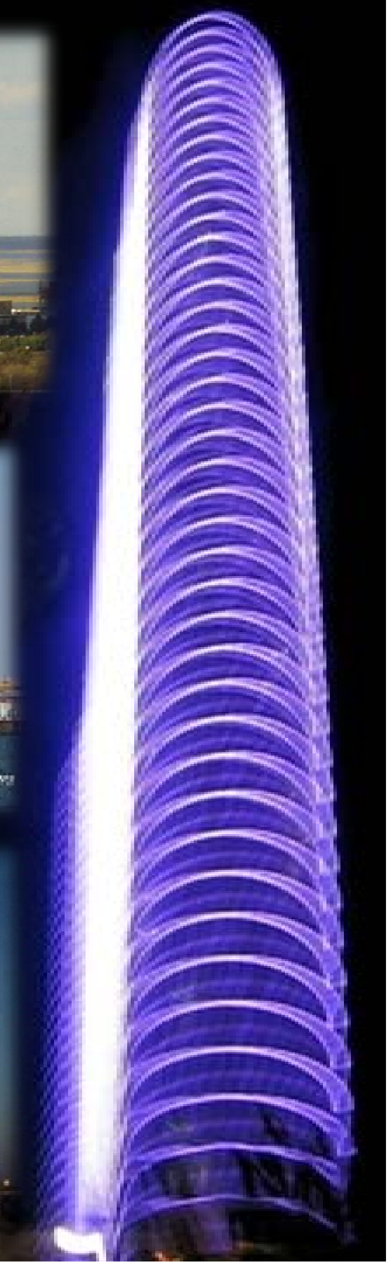
- Building Introduction
- Design Concerns
- Structural Proposal
- Structural Depth
  - Lateral Redesign
  - Gravity Redesign
- Construction Management Breadth
- Architectural Breadth



Building Introduction

- Location - Atlantic City, New Jersey
- 416 ft at Roof Level
- 43 Stories Above Grade
- 8’-9” Typical Floor-to-Floor Height
- 35,000 SF Floor Plate – Total 1.5M SF



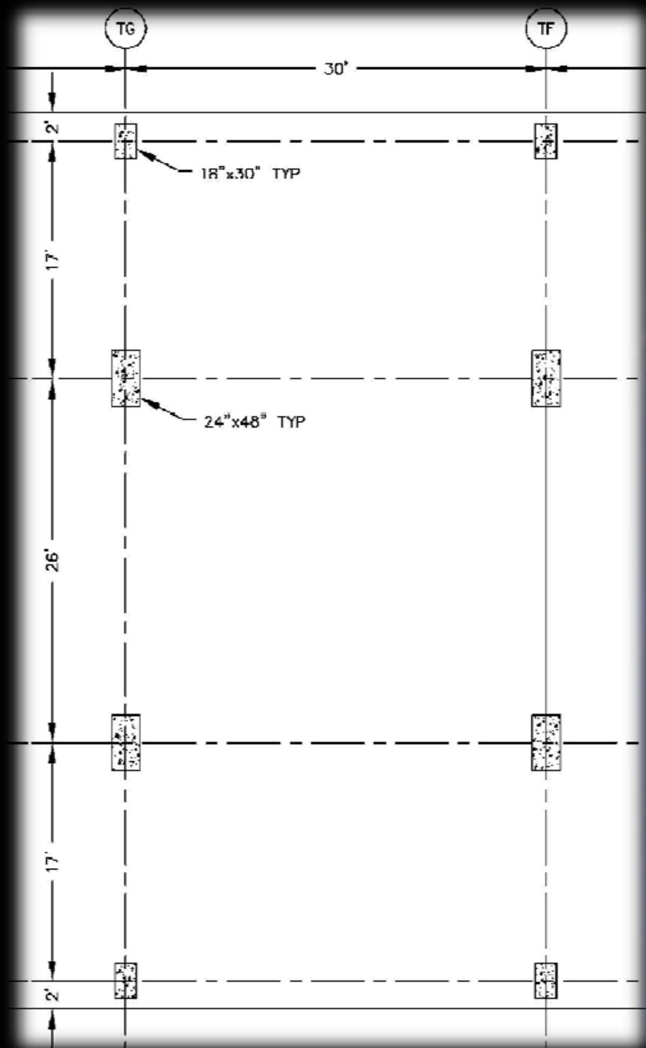


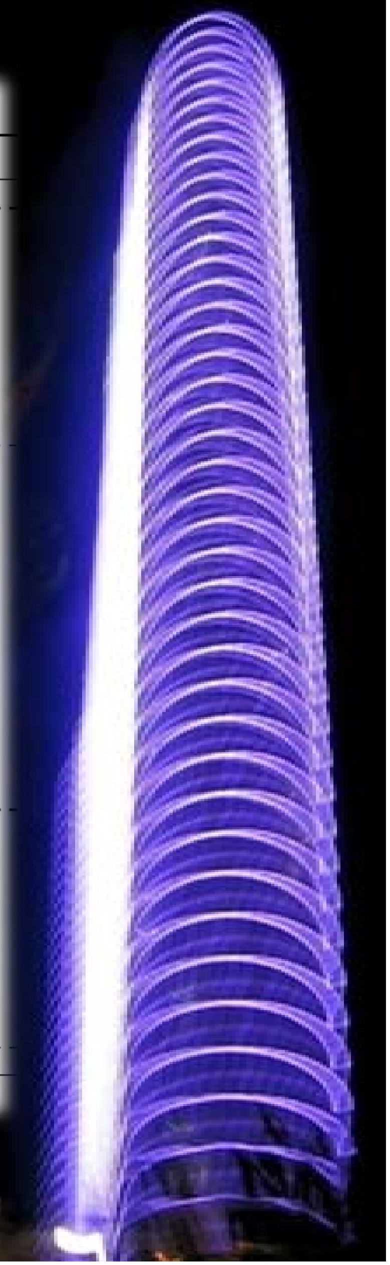
Building Introduction

- Project Team
  - Owner - Boyd Gaming and MGM MIRAGE
  - Structural - Cagley Harman and Associates
    - Now The Harman Group
  - Architect - Marnell Corrao

Existing Structural System

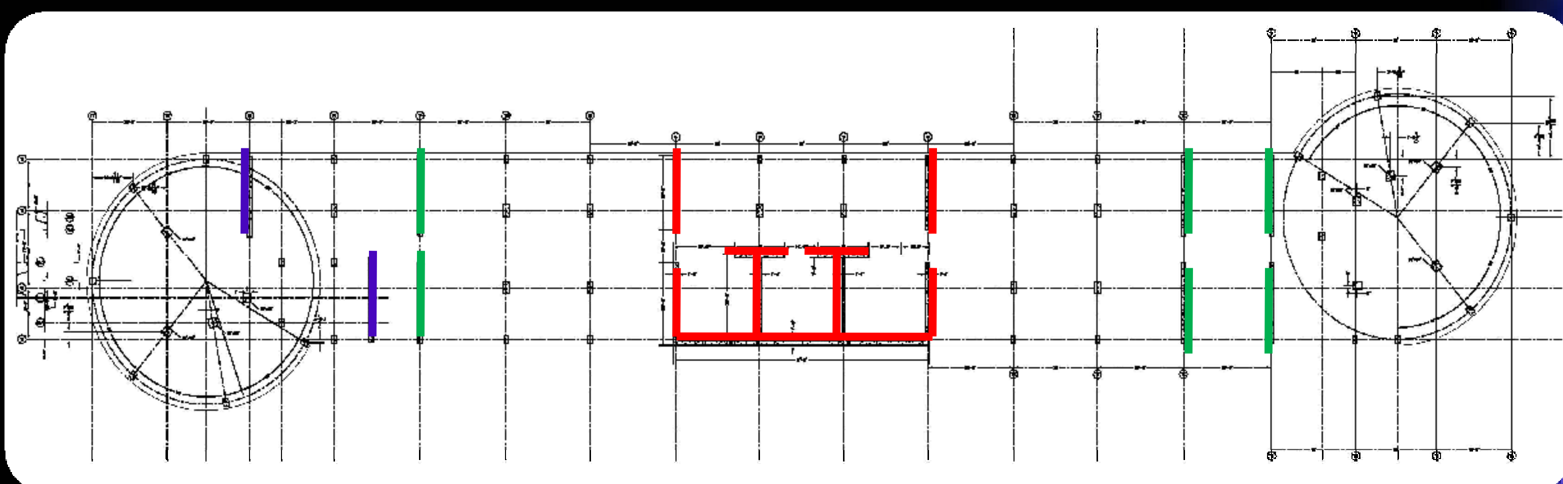
- Gravity System
  - Post-Tensioned Flat Plate
    - 7” thick (8.5” thick at circular ends of building
  - Typical bays are 17’x30’; 26’ x 30’
  - Typical Column Sizes of 18x30 and 24x48
    - f’c changes with building height
      - Floors 1 to 12 – 9 ksi
      - Floors 13 to 22 – 7ksi
      - Floors 23 and up - 5 ksi



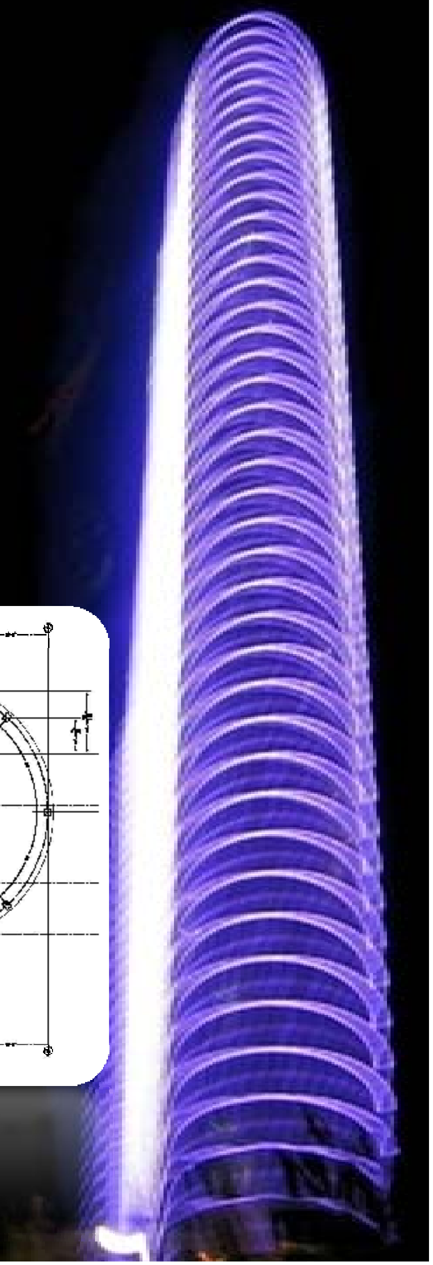


Existing Structural System

- Lateral System
  - Reinforced concrete shear walls
    - Coupled walls
    - Regular walls
    - Core walls
  - F'c = 9 ksi for ALL walls

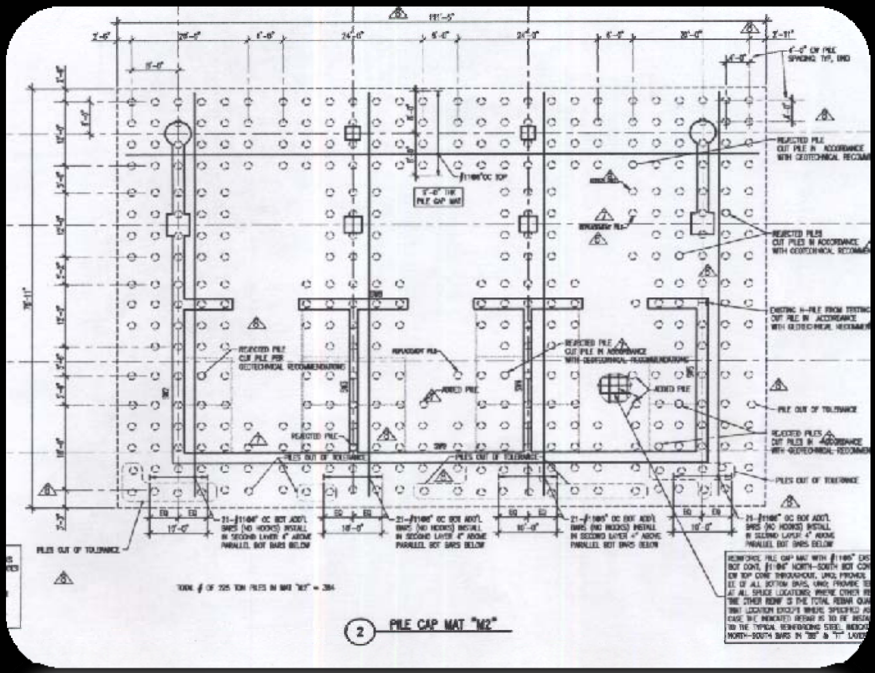


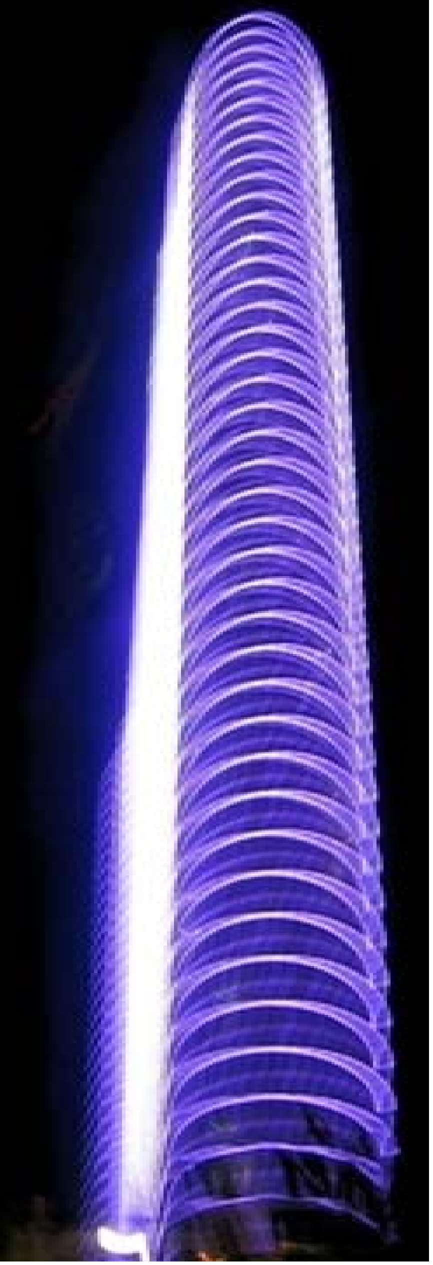
Regular Walls   Coupled Walls   Core Walls



Existing Structural System

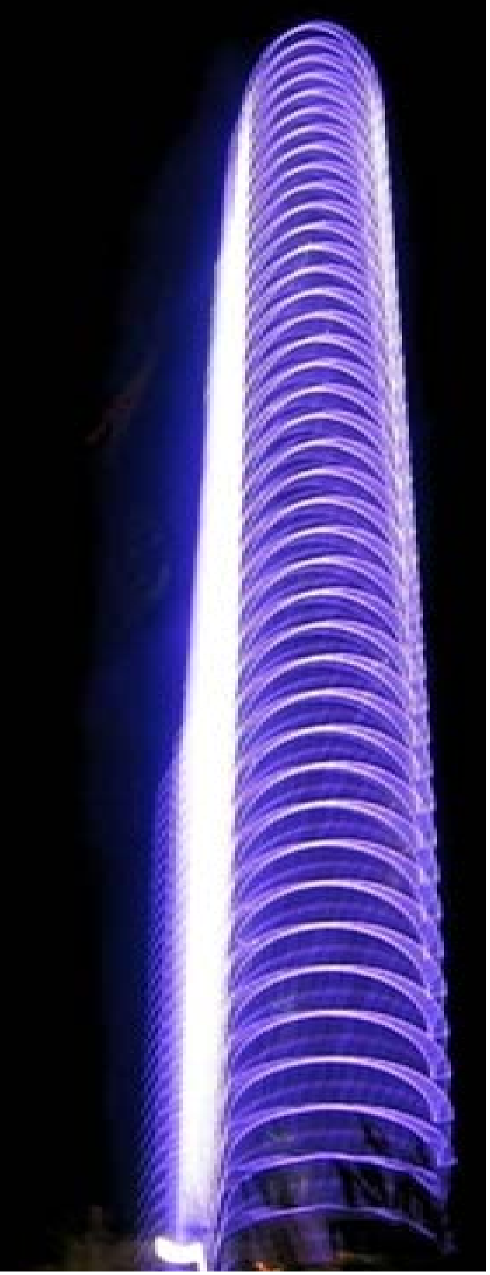
- Foundations
  - Core and Shear Walls – Mat slabs supported by piles
  - Columns – Pile caps supported by piles
  - Piles – 16 Φ steel tubes filled with reinforced Concrete
    - 225 ton capacity each





Design Concerns

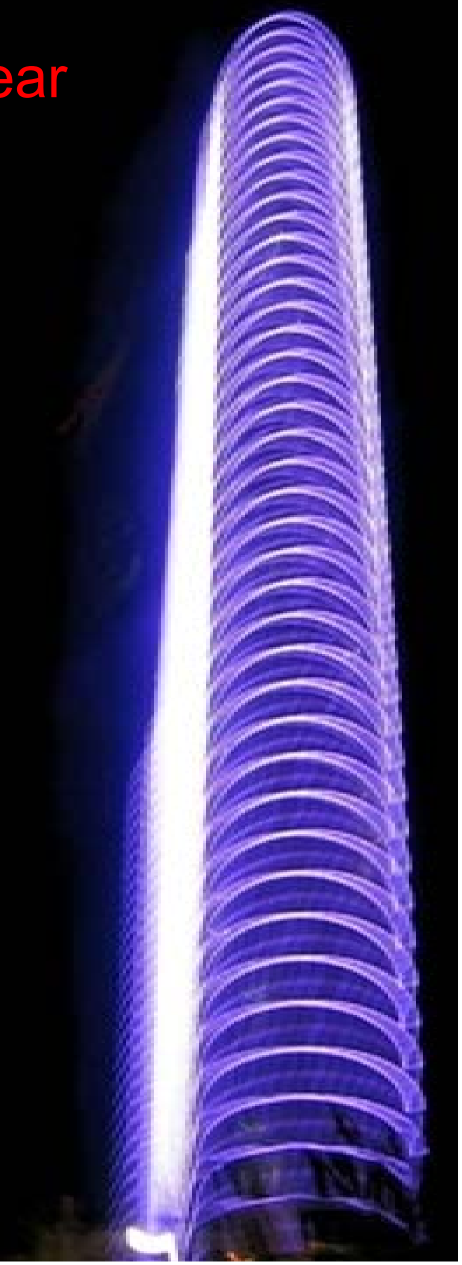
- Lateral Design
  - Large number of large walls
  - Core has complex geometry
  - Layout non-symmetric = torsion
- Gravity System
  - Post-tensioning systems are high in cost
  - Labor intensive
  - Long schedule



Structural Proposal

- Redesign lateral system using a more efficient shear wall design

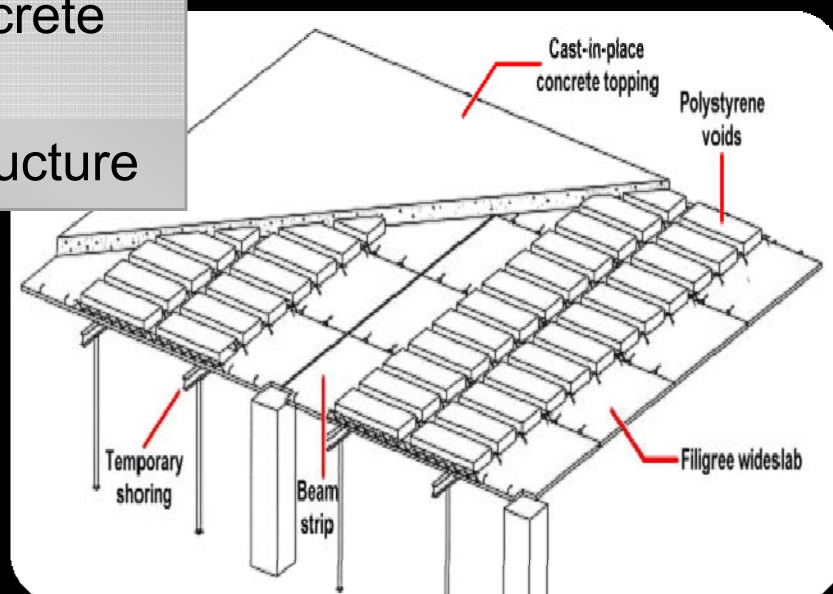
GOALS
Reduce the overall size of the lateral system
Reduce number of individual walls
Reduce the size of the core
Create redundancy in the system
Create symmetry

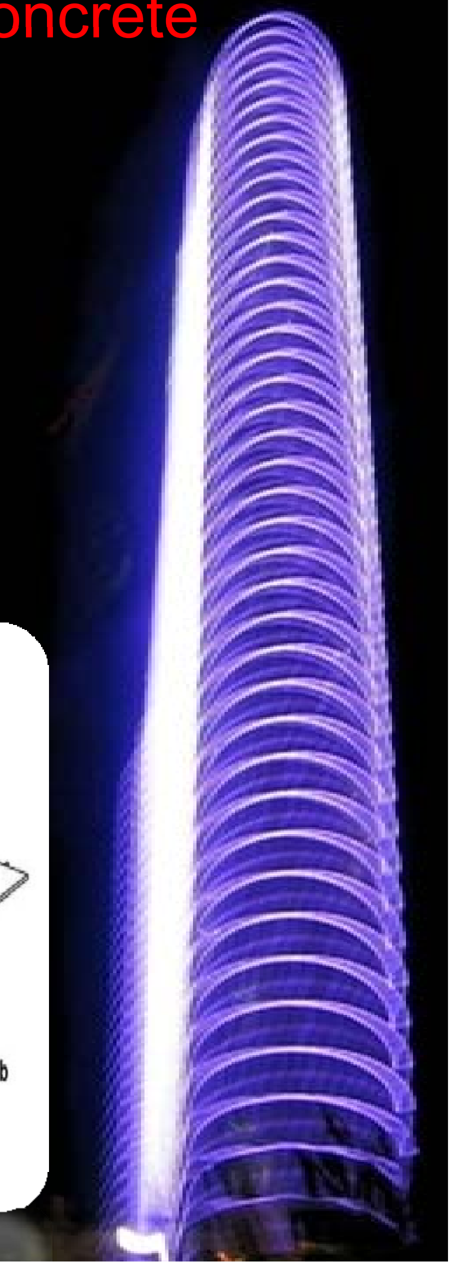


Structural Proposal

- Redesign the floor system using a composite concrete floor system
  - Manufactured Mid State Filigree
    - Filigree wide slab system

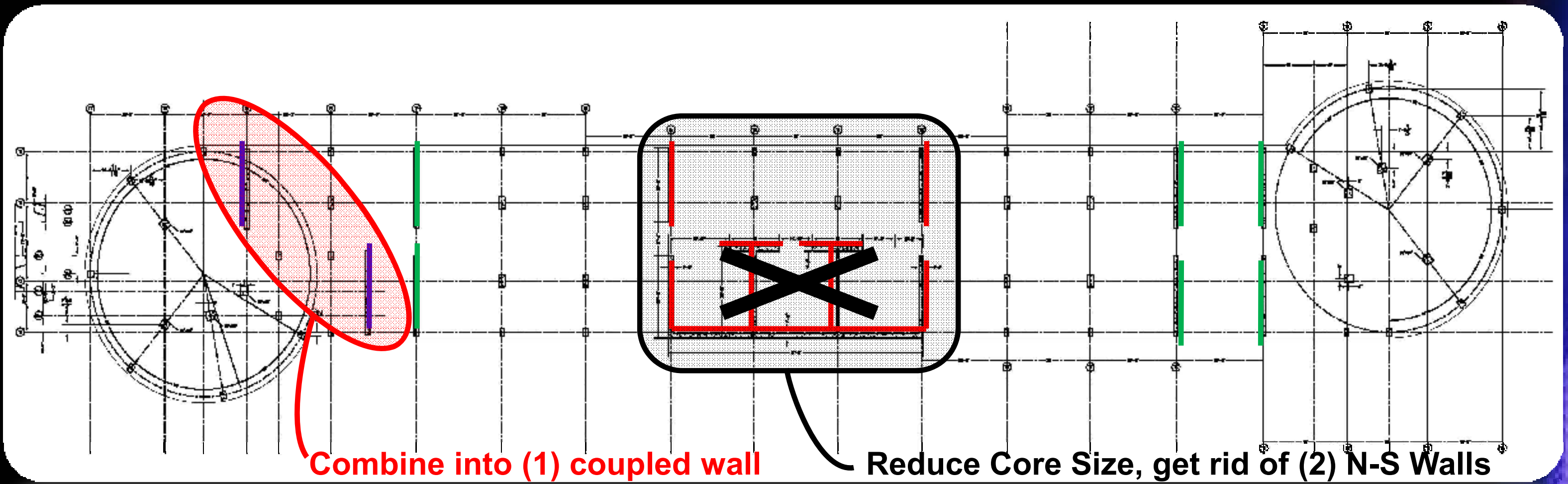
Goals
Reduce erection schedule
Reduce construction costs
Reduce amount of concrete used
Reduce weight of the structure





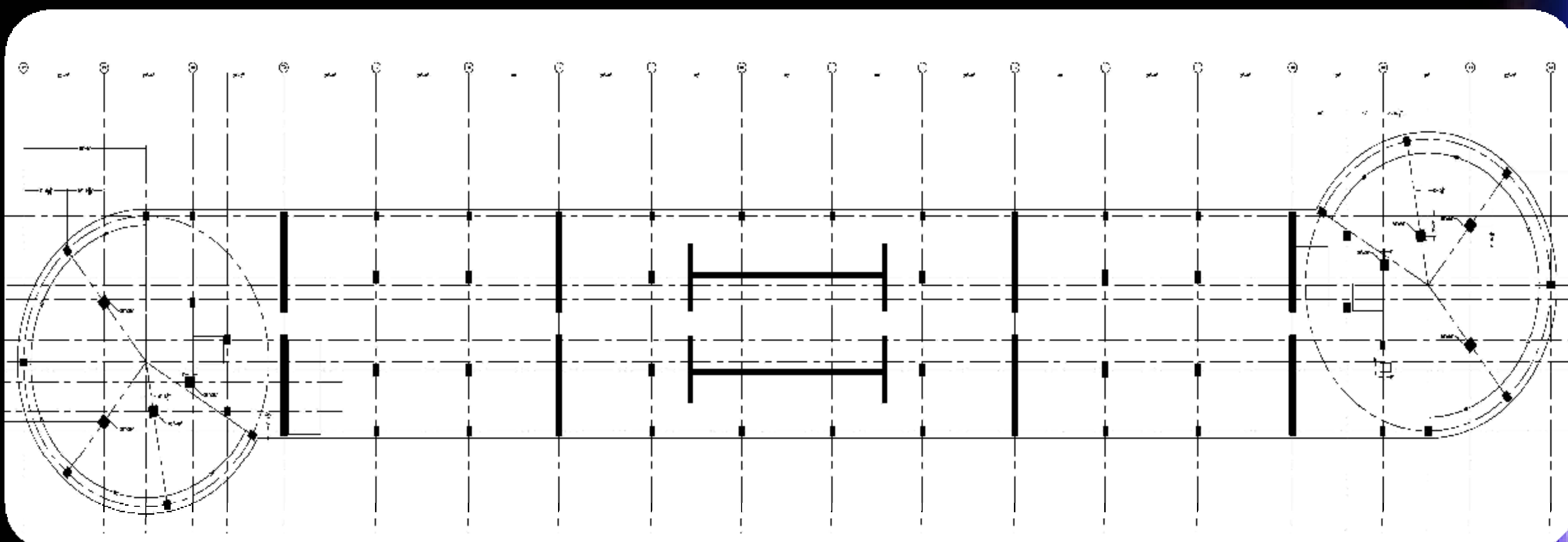
Lateral System Redesign

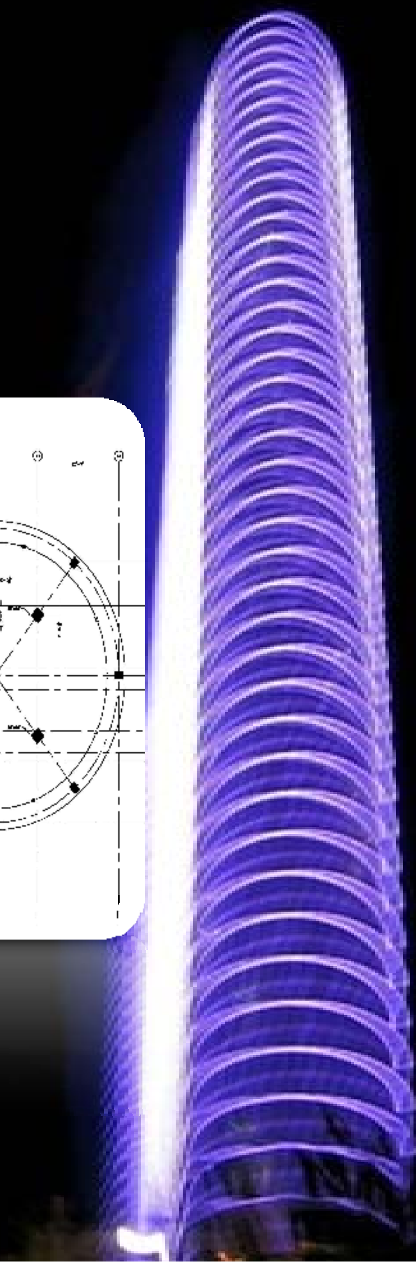
- Must reduce the size and complexity of system, while resisting the same loads while working with the architecture



Lateral Redesign

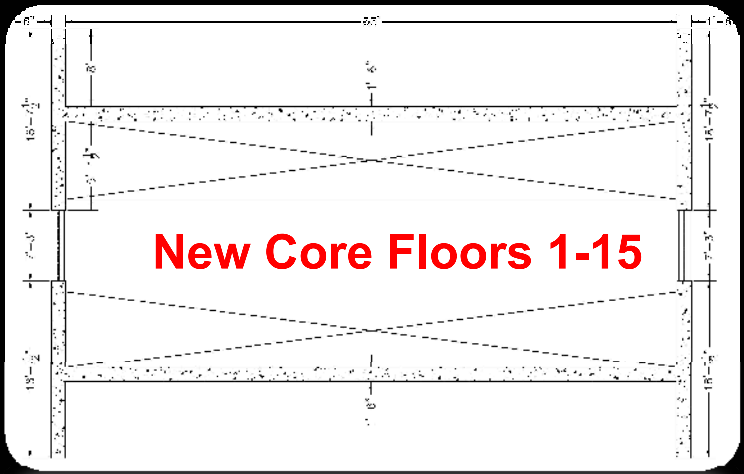
- New shear wall layout
  - Core reduced and centered over COM
  - Coupled walls same and symmetric

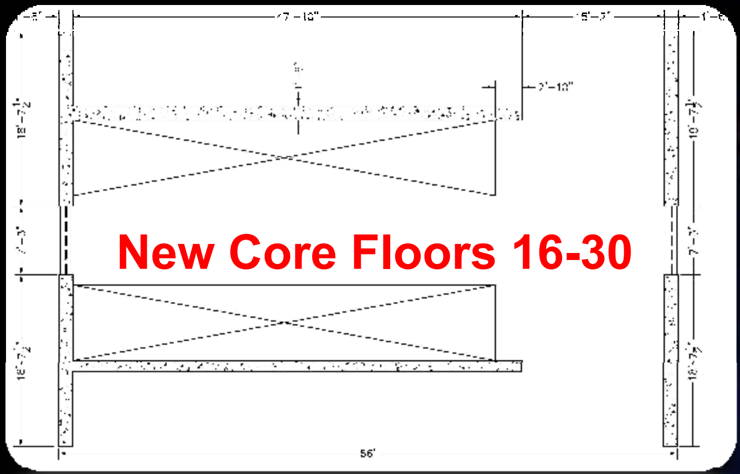


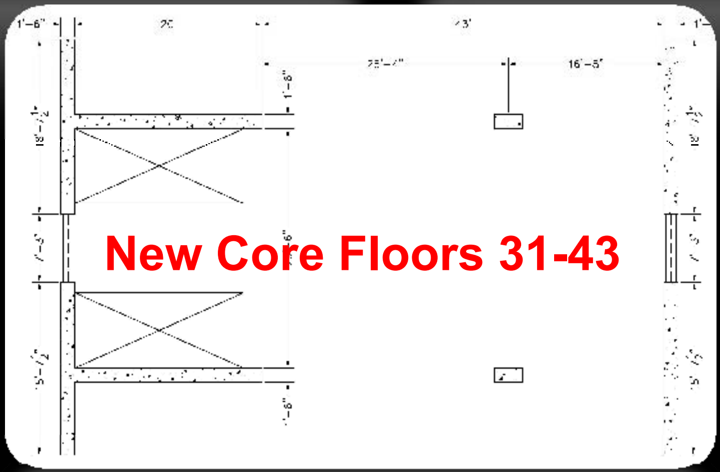


Lateral Redesign

- New core design
  - (2) N-S resisting elements
  - (2) E-W resisting elements
  - Both I-shapes coupled at flange elements

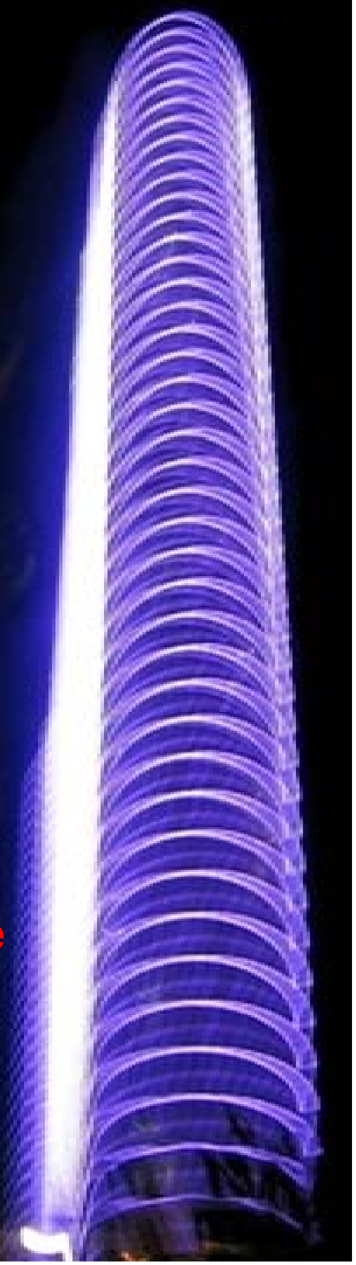






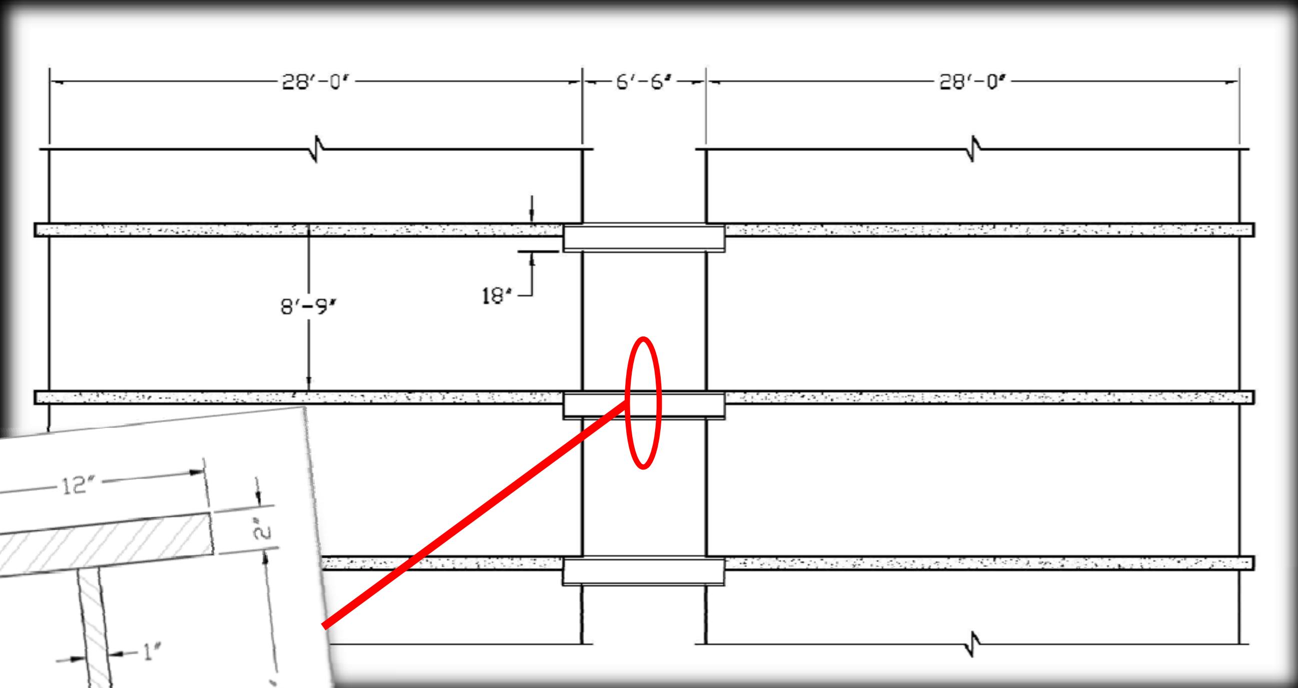
18” thick for all core wall elements

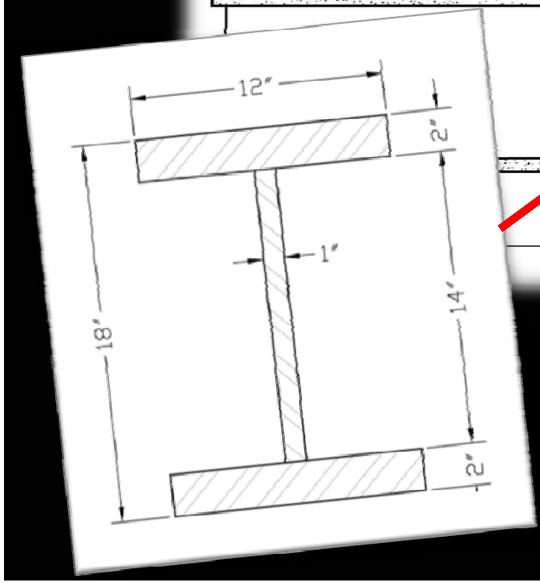
f’c = 9000 psi



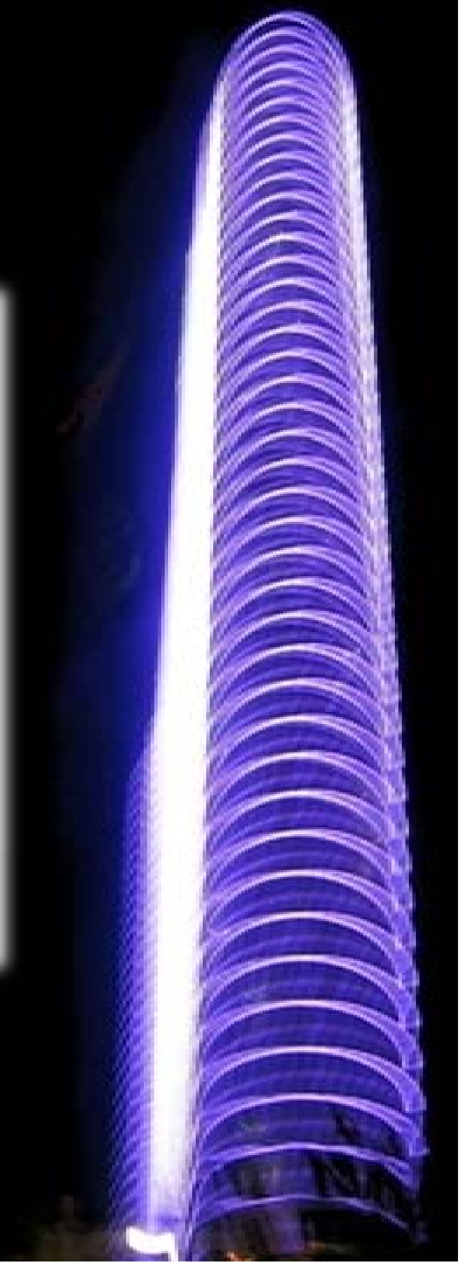
Lateral Redesign

- New coupled wall design
  - (2) 24” thick by 28’-0” long piers
  - Coupled by built up steel section @ 6’-6” long



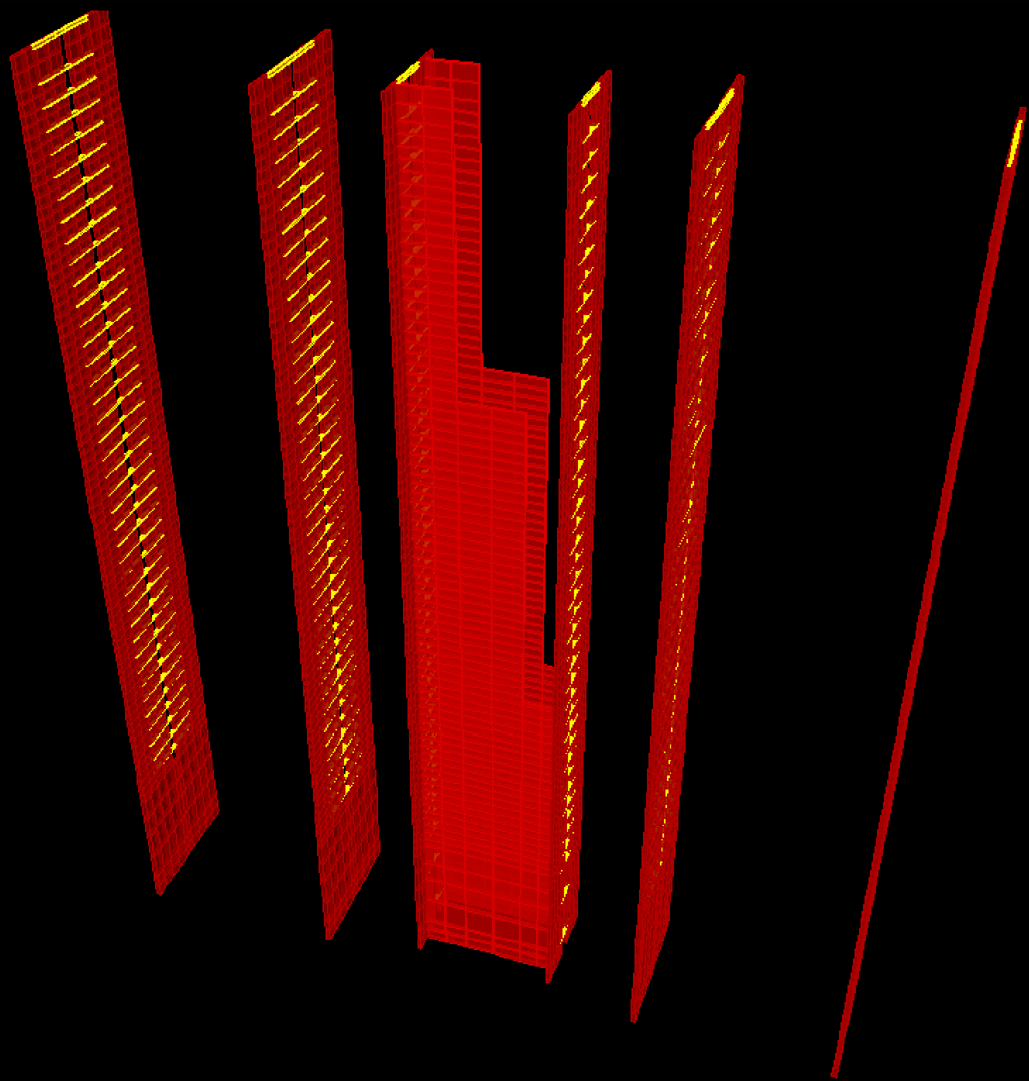


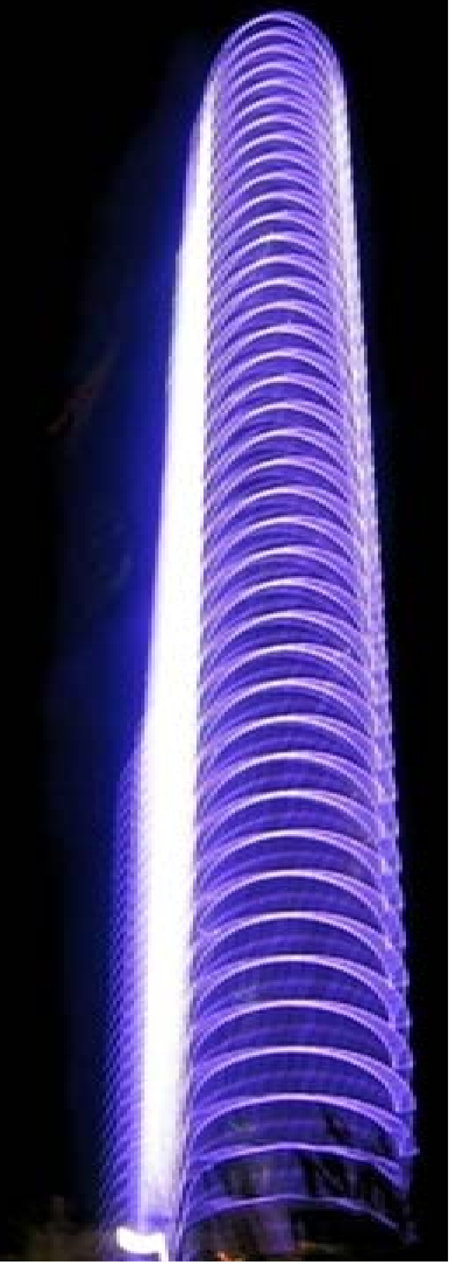
f’c = 9000 psi
A992 or A572 Gr. 50 Coupling Beams



Lateral Redesign

- Lateral System modeled using ETABS Nonlinear V9.2



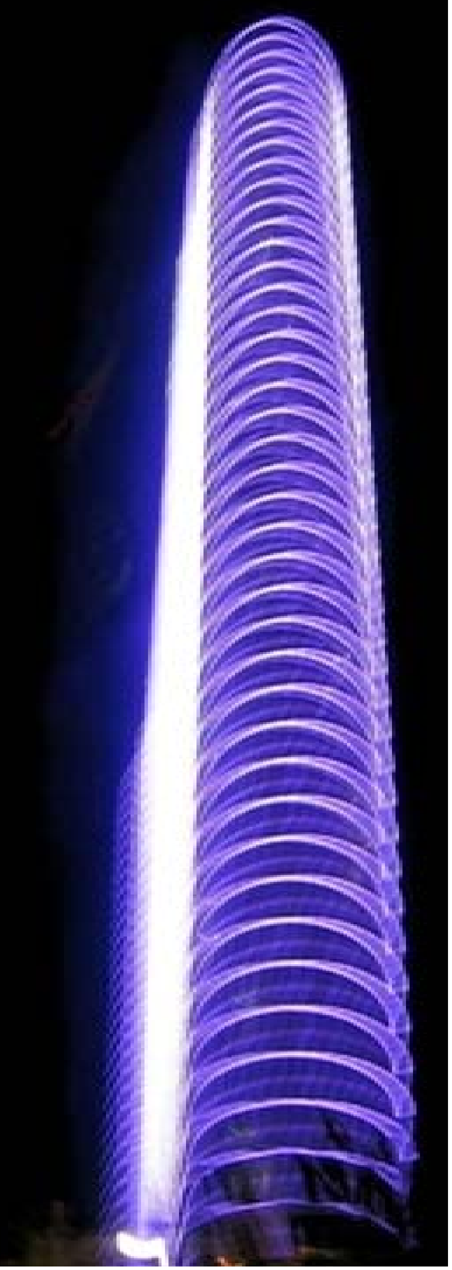


Lateral Redesign

Natural Periods of Vibration

Existing - Natural Period of Vibration	
Mode 1	4.309 seconds
Mode 2	3.196 seconds
Mode 3	2.596 seconds

Redesign - Natural Period of Vibration	
Mode 1	2.184 seconds
Mode 2	1.726 seconds
Mode 3	1.575 seconds

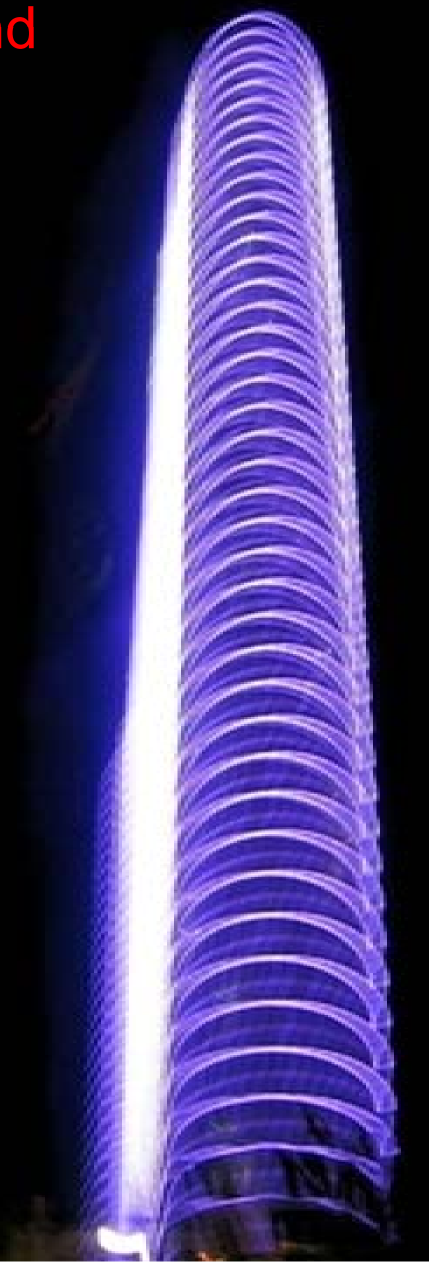


Lateral Redesign

Lateral drifts at roof level of existing design under wind loading

WIND LOAD DISPLACEMENTS EXISTING DESIGN				
	ΔX (in)	Drift (in/in)	ΔY (in)	Drift (in/in)
Load Case 1X	4.40	H/1135	0.00	---
Load Case 1Y	0.00	---	11.42	H/437
Load Case 2	4.69	H/1064	8.88	H/562
Load Case 3 X	3.20	H/1560	0.00	---
Load Case 3 Y	0.00	---	6.89	H/726
Load Case 4	1.77	H/2820	5.41	H/923

Drift Limit = H/400



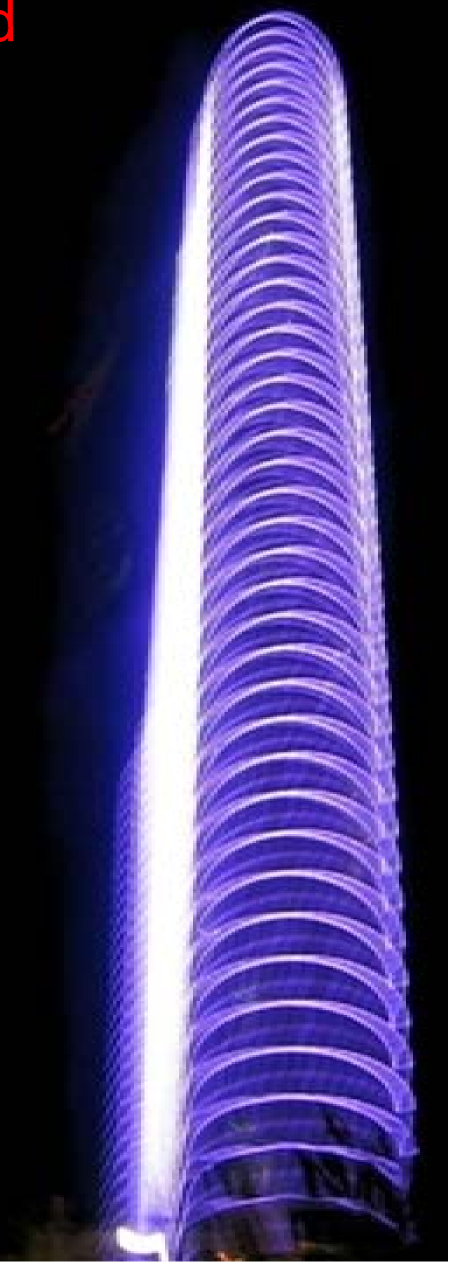
Lateral Redesign

Lateral drifts of the new system under reduced wind loads

REDUCED WIND LOADS (0.7 X WIND)				
	ΔX (in)	Drift	ΔY (in)	Drift
Load Case 1X	2.84	H/1667	0	---
Load Case 1Y	0	---	7.75	H/625
Load Case 2	2.13	H/2500	5.90	H/833
Load Case 3 X	2.13	H/2500	0	---
Load Case 3 Y	0	---	5.93	H/833
Load Case 4	1.60	H/3333	4.45	H/1111

Drift limit = H/400

- Max inter story drift at floors 30 and 31; 0.207 inches or H/507



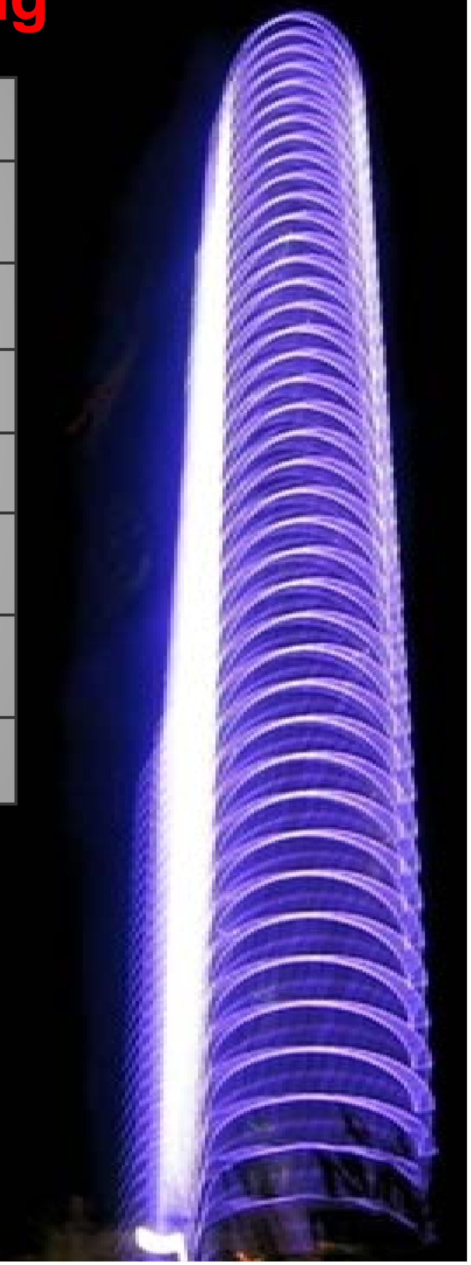
Lateral Redesign

Drifts at roof level due to full wind loading

FULL WIND LOADS				
	ΔX (in)	Drift (in/in)	ΔY (in)	Drift (in/in)
Load Case 1X	4.06	H/1250	0	---
Load Case 1Y	0	---	11.07	H/454
Load Case 2	3.04	H/1667	8.43	H/588
Load Case 3 X	3.04	H/1667	0	---
Load Case 3 Y	0	---	8.47	H/588
Load Case 4	2.29	H/2000	6.36	H/769

Drift Limit = H/400

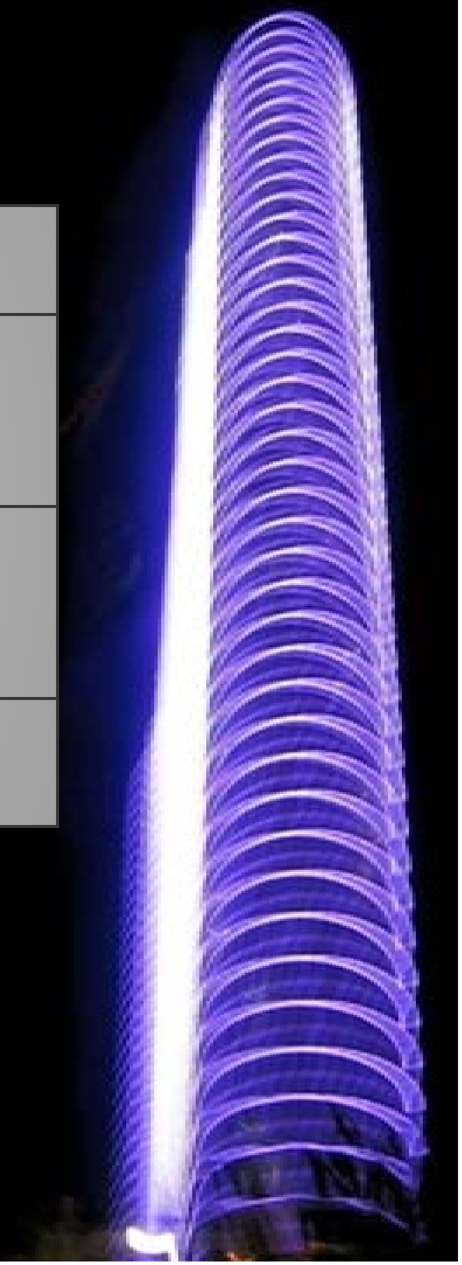
- Max inter story drift at floors 30 and 31; 0.295 inches or H/356



Lateral Redesign

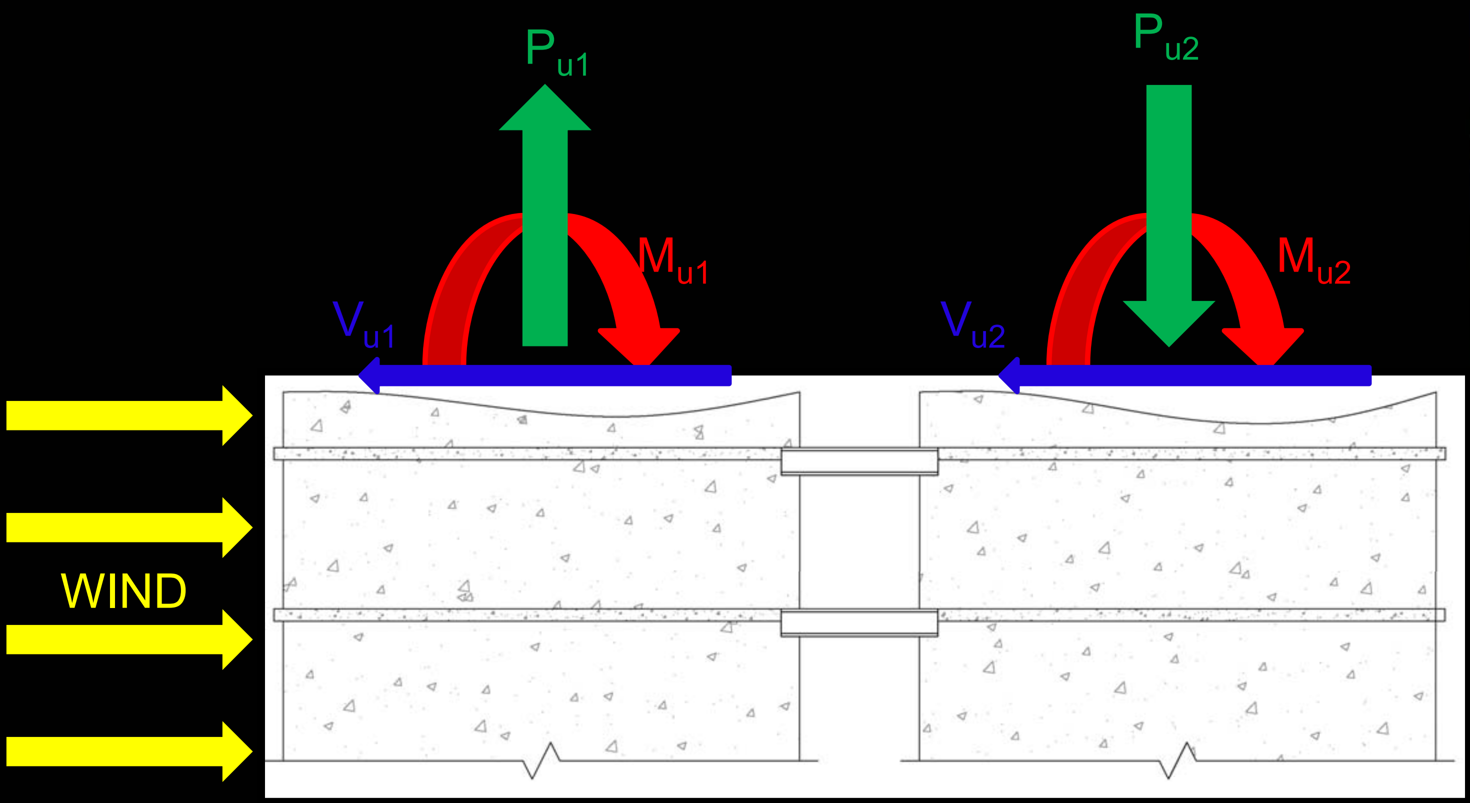
Drifts due to seismic loading

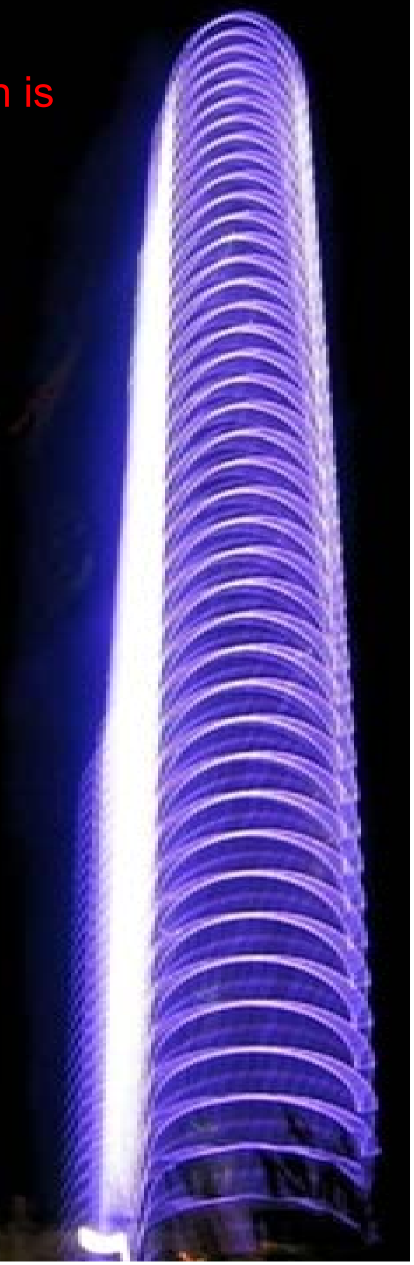
$DRIFT \times C_d \le 0.020 \times H_{sx}$	
Max Drift = 5.28”	5.28 × 4.0 = 21.12” *is less than* 4992 × 0.02 = 99.84”
Max Inter-Story Drift = 0.338”	0.338 × 4.0 = 1.352” *is less than* 153 × 0.02 = 3.06”
**Lateral design meets seismic drift requirements*	



Lateral Redesign

- Strength design is controlled by wind loading
  - The predominant load combination controlling reinforcement design is 0.9Dead + 1.6Wind



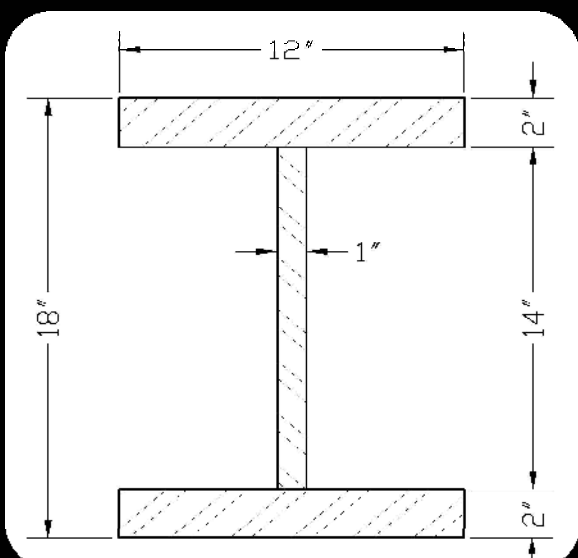


Lateral Redesign

- Coupling Beam Design
  - *Most important part of coupled walls!*
  - For this thesis, all beams were designed for max forces

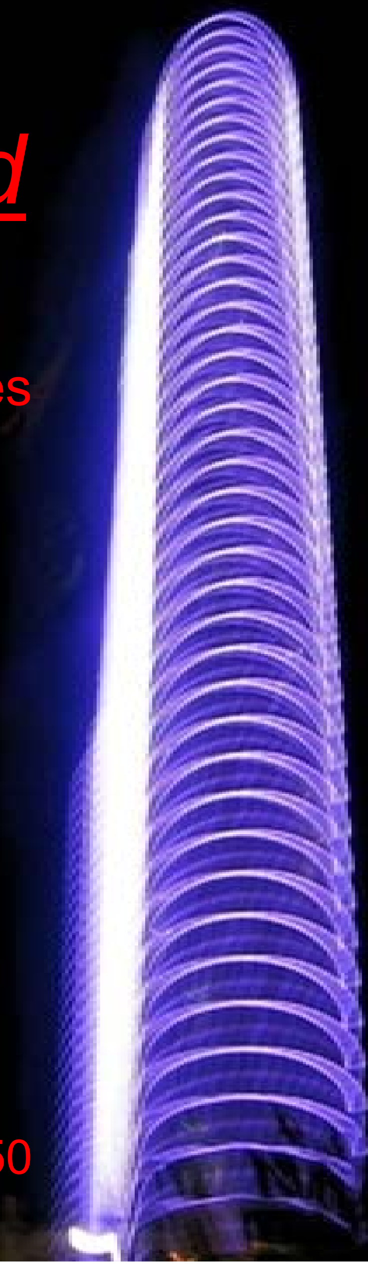
M_u = 15,240k-in = $\Phi M_p = \Phi\, F_y{*}Z$

$Z_{req'd} = Mu/(\Phi\, F_y)$ = (15,240k-in) /(0.9 × 50ksi) = 343.7in^3



Area = 62.0 in^2
I_x = 3,345.0 in^4
Z_x = 439.1 in^4
W = 210 plf
ΦM_p = 19,759 k-in

*Uses A992 or A572 Gr. 50



Lateral Redesign

- Approximate Reinforcing Design
  - As Boundary Element

    $\Phi M_n = A_s f_y(0.8L - a/2)$ Solving For A_s

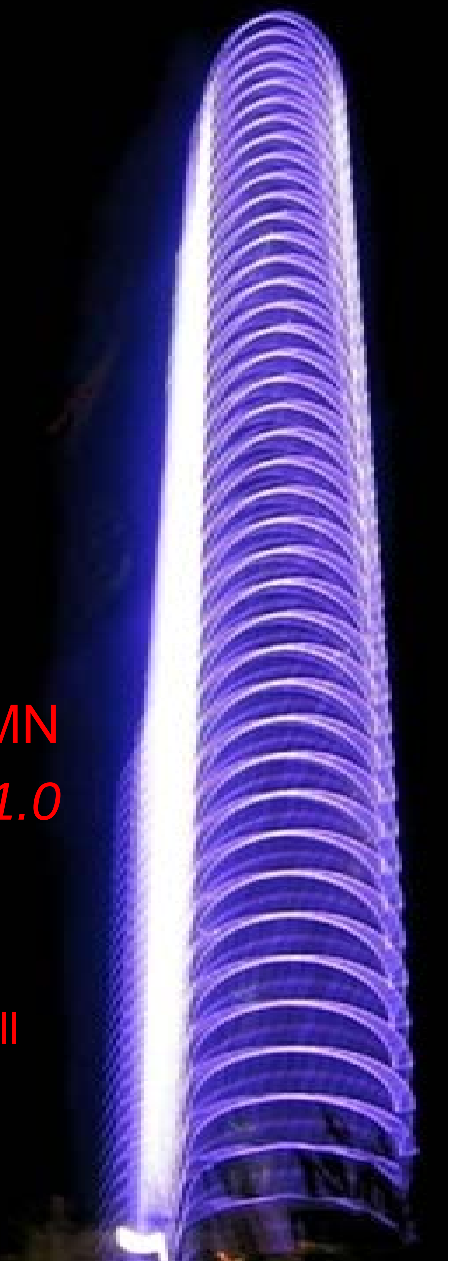
  - As uniformly distributed

    $\Phi T_n = A_s f_y$ Solving for A_s

- Solve for approximate steel, then refine in PCA COLUMN

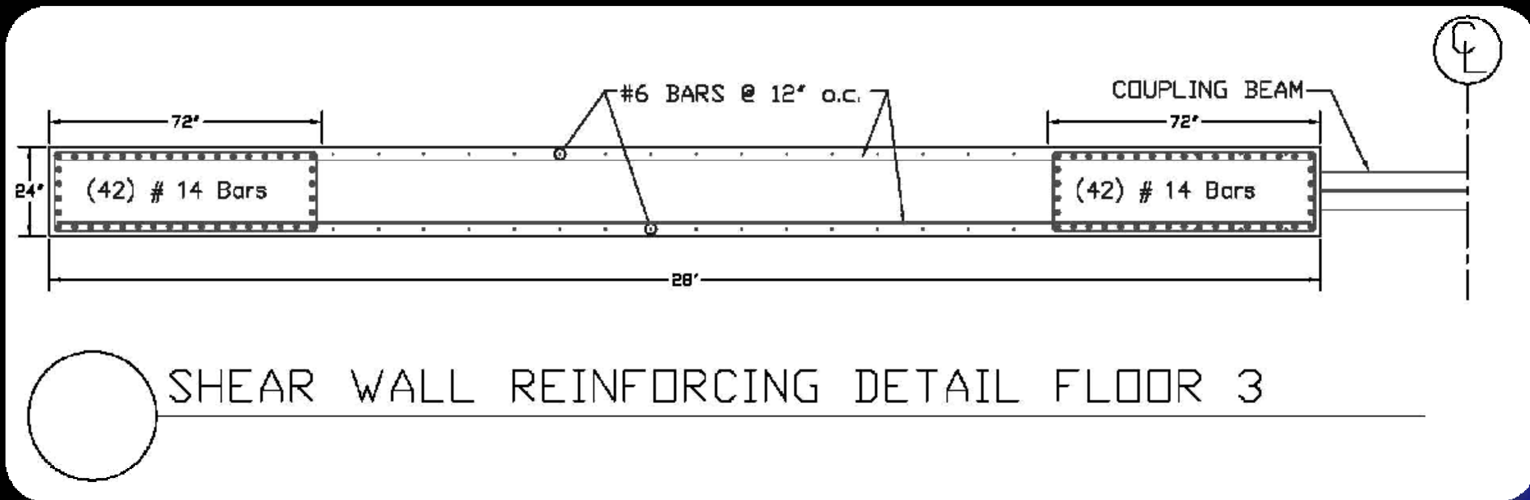
  AIM – Achieve Nominal Strength / Ultimate Load = 1.0

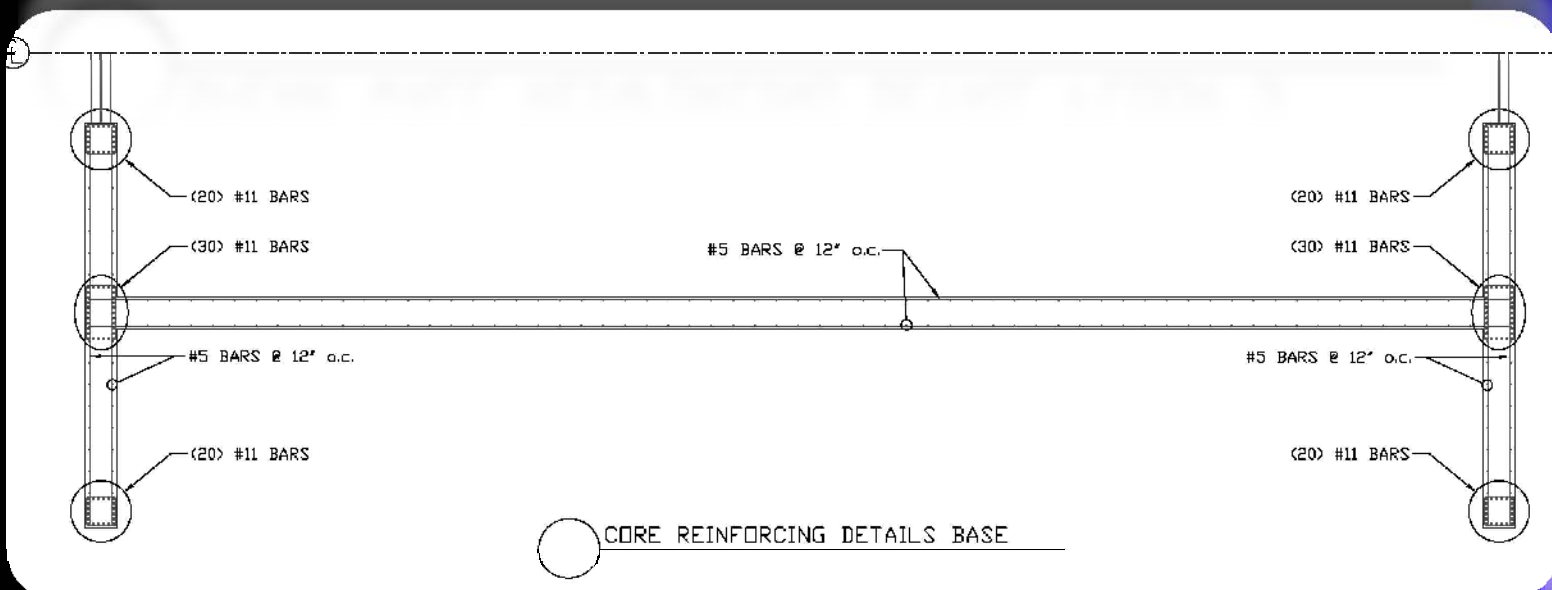
- Shear Reinforcing
  - Since walls are so large, minimum reinforcing was used for all transverse reinforcing
    - #6 Bars @ 12” o.c.

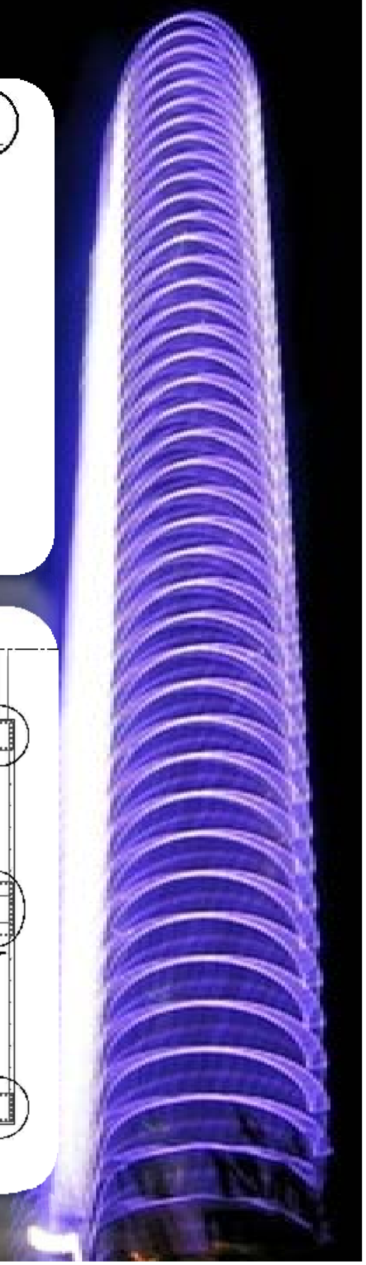


Lateral Redesign

- Final Reinforcement Designs

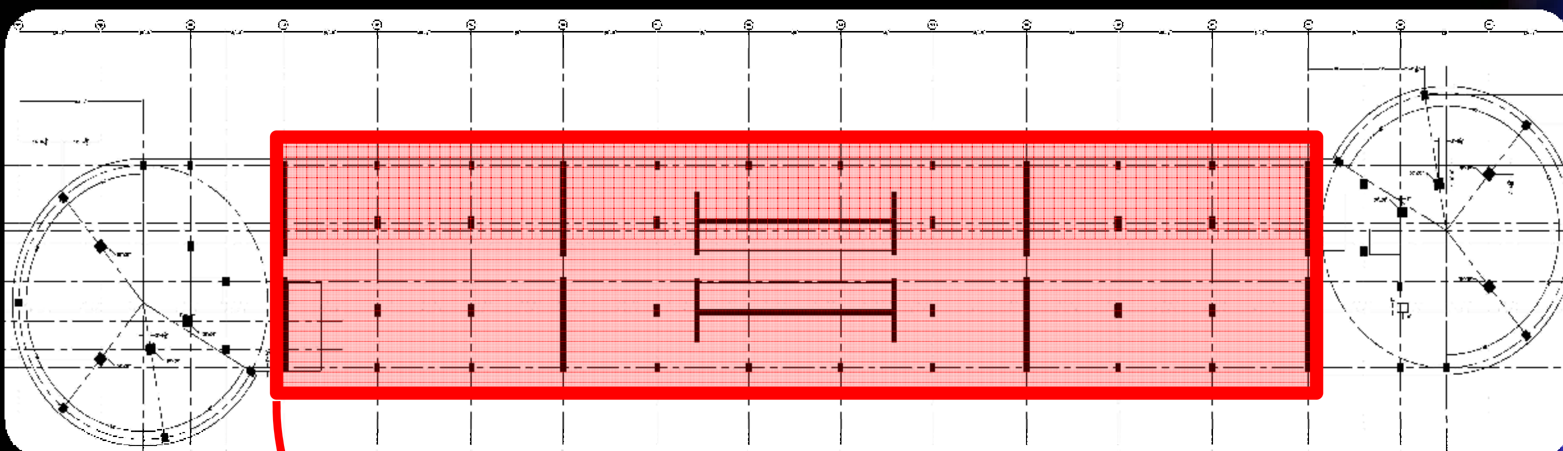




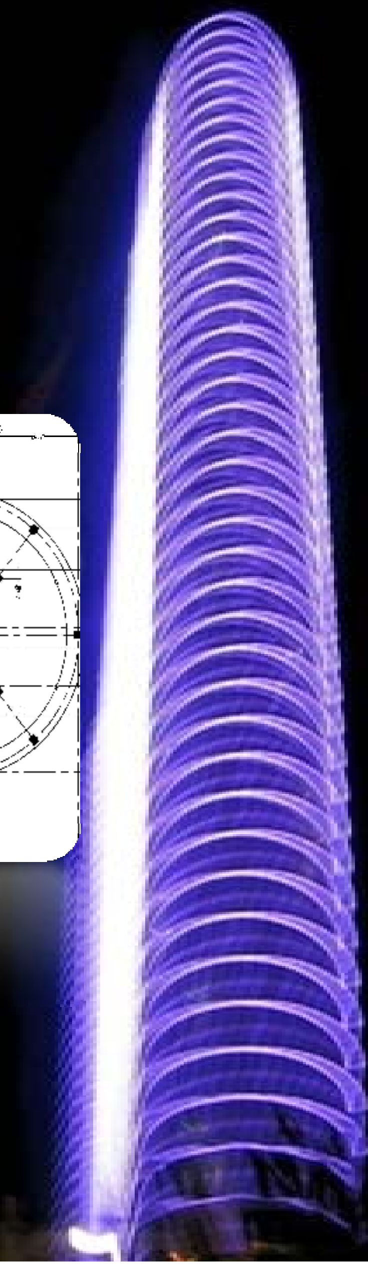


Gravity Redesign

- New slab system – Filigree system by Mid State Filigree in New Jersey

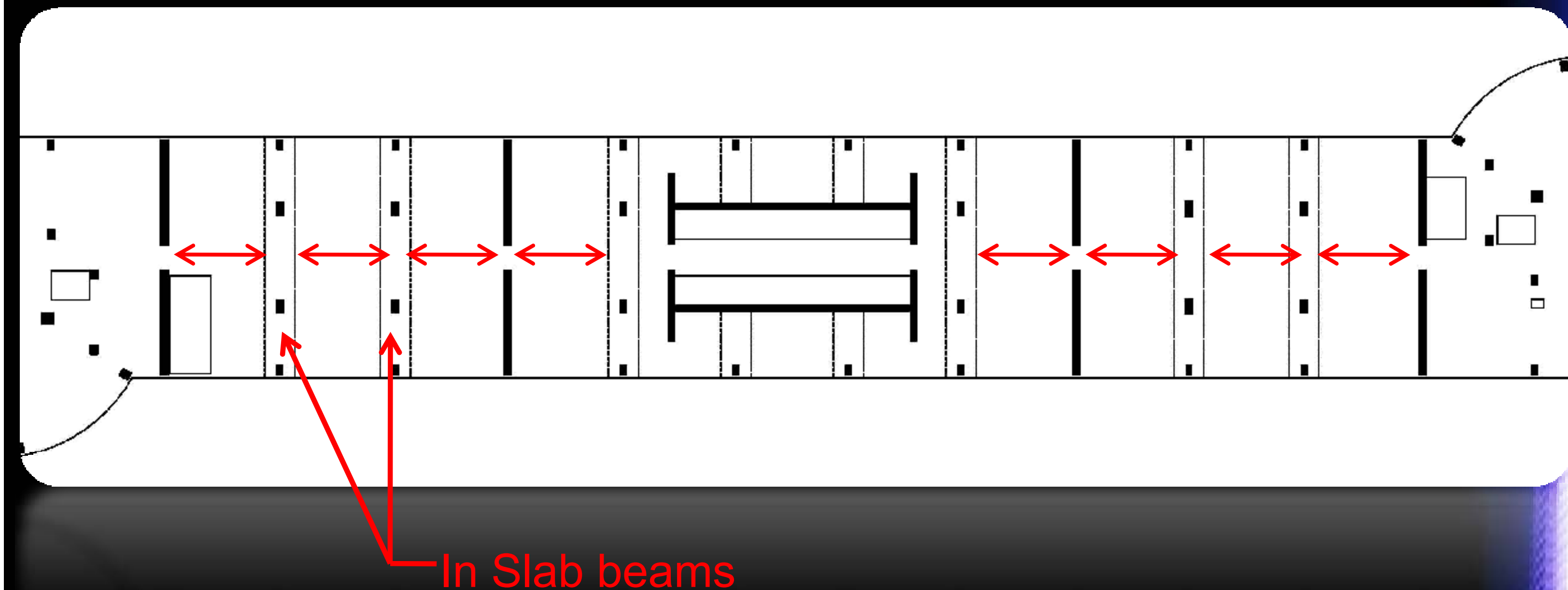


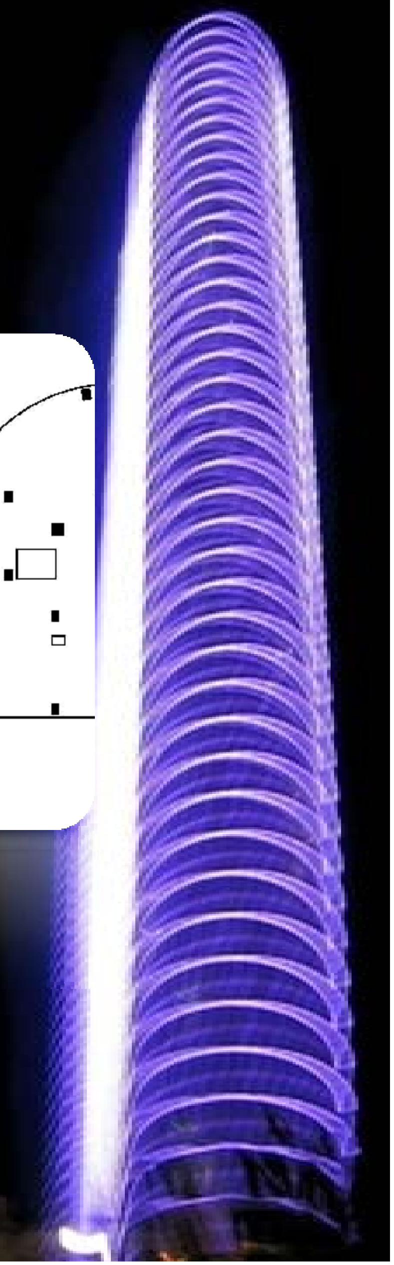
Redesign enclosed part of slab in filigree



Gravity Redesign

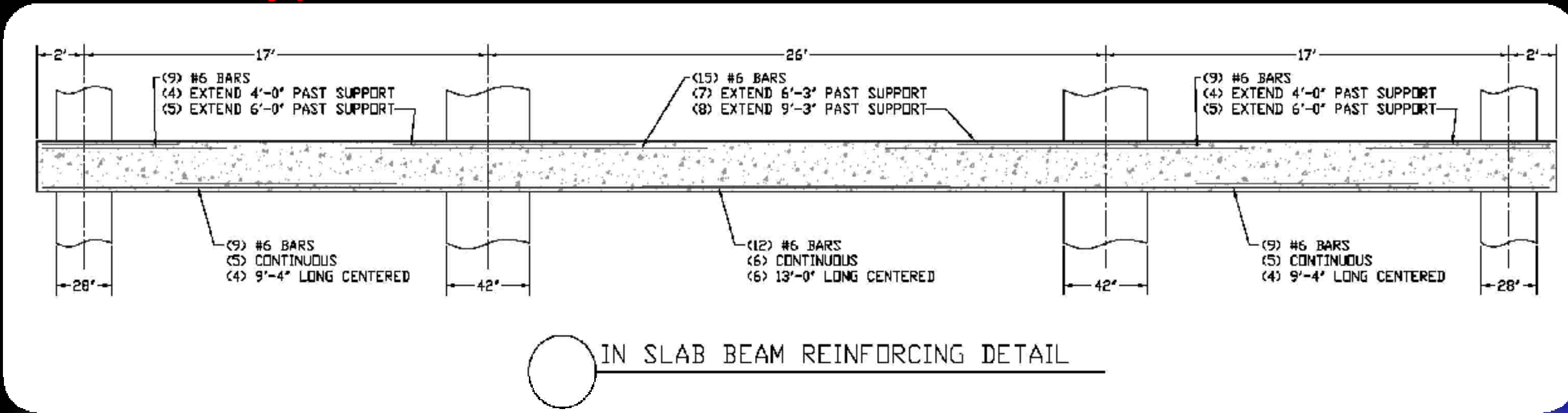
- System uses one way slab with 96 wide in slab beams



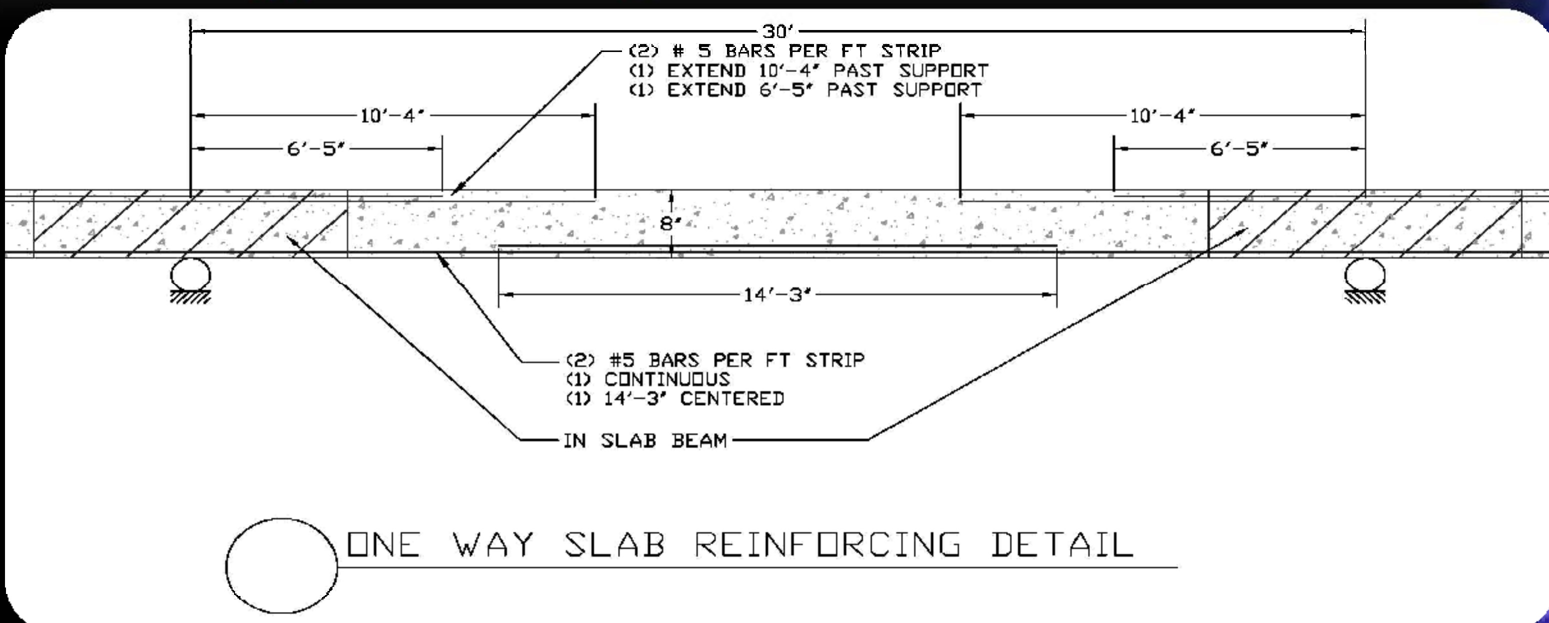


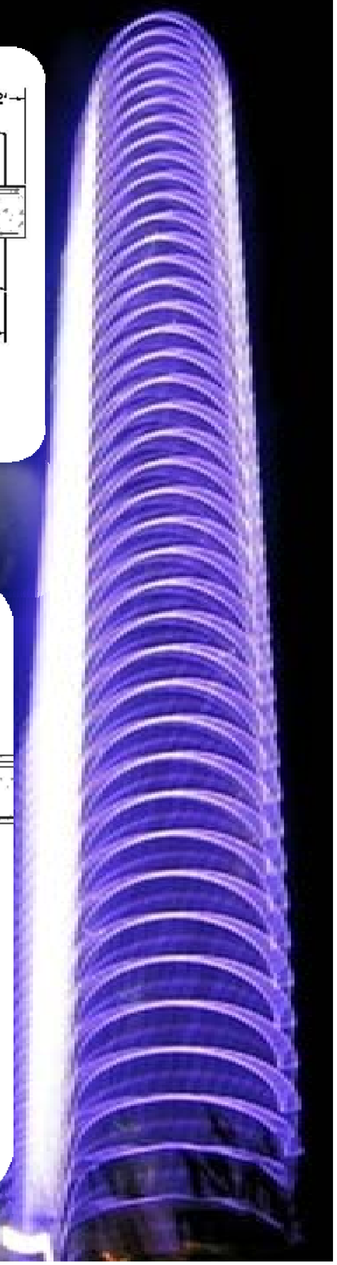
Gravity Redesign

- Typical In Slab Beam Reinforcement



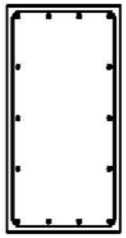
- Typical One Way Slab Reinforcement

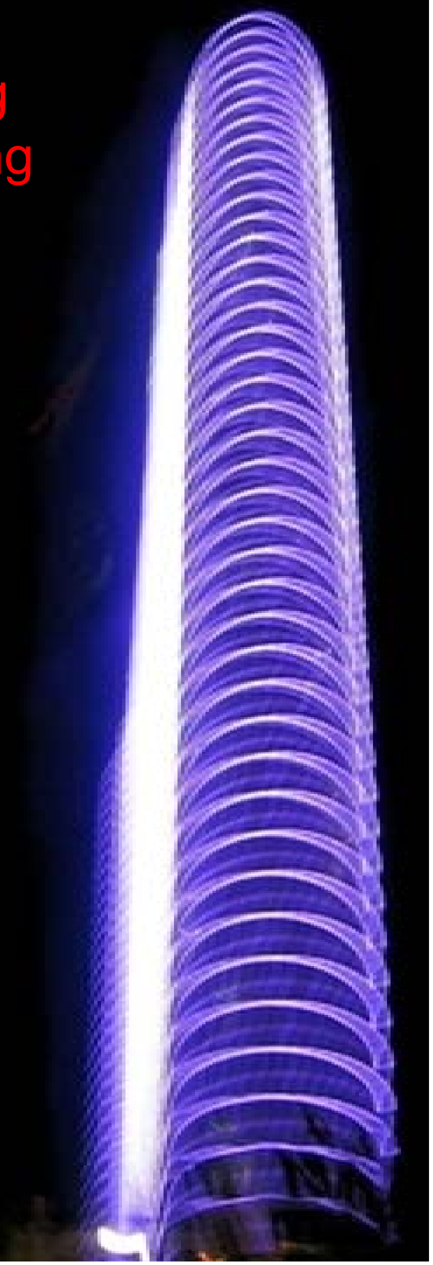




Gravity Redesign

- Typical Column Size Reductions
  - With voided slab, dead loads are lower – reducing size of concrete columns and amount of reinforcing

REDESIGN COLUMN SCHEDULE	
TYPICAL INTERIOR COLUMN DIMENSIONS 21″ X 42″ REINFORCING (14) #8 BARS	
TYPICAL EXTERIOR COLUMN DIMENSIONS 16″ X 28″ REINFORCING (8) #8 BARS	



Breadth Study – Construction Costs

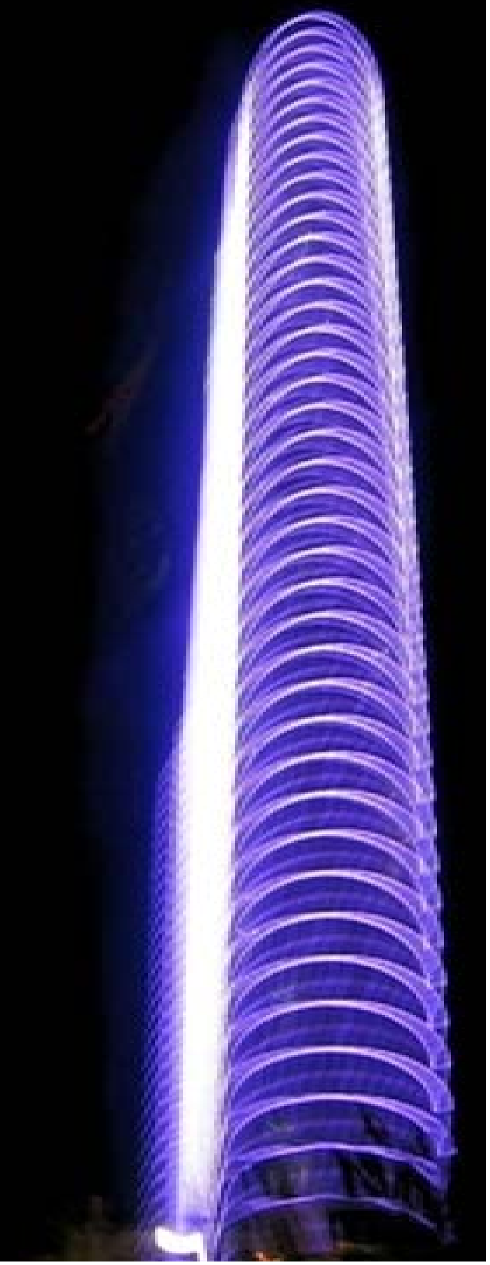
Original Shear Wall Design	
Total Cubic Yards	11,703
Concrete Cost	$2,873,000

New Shear Wall Design	
Total Cubic Yards	10,738
Concrete Cost	$2,636,000

<u>SAVINGS</u>

966 CY of Concrete

$237,000



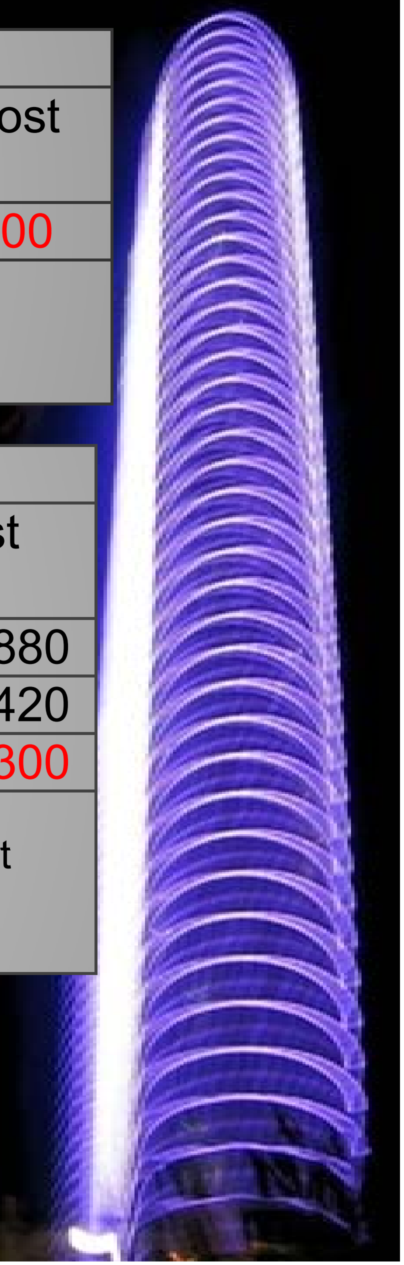
Construction Management Breadth

ORIGINAL COUPLING BEAM TAKEOFF						
Coupled Walls	Beams per wall	Length	PLF	Tons	Cost / L.F.	Total Cost
5	40	11.5	112	128.8	$136	$312,800

*Coupling beams are rolled wide flange sections priced per linear foot using RSM Means

NEW COUPLING BEAM TAKEOFF						
Coupled Walls	Beams per Wall	Length	PLF	Tons	Cost / L.F.	Cost
4	40	8.5	210	142.8	$261	$384,880
2	40	9.25	210	77.7	$261	$209,420
					Total	$594,300

*Coupling beams are built up sections using A992 steel plates priced per linear foot using an adjusted cost for a close to equivalent weight per foot rolled wide flange section using RS Means



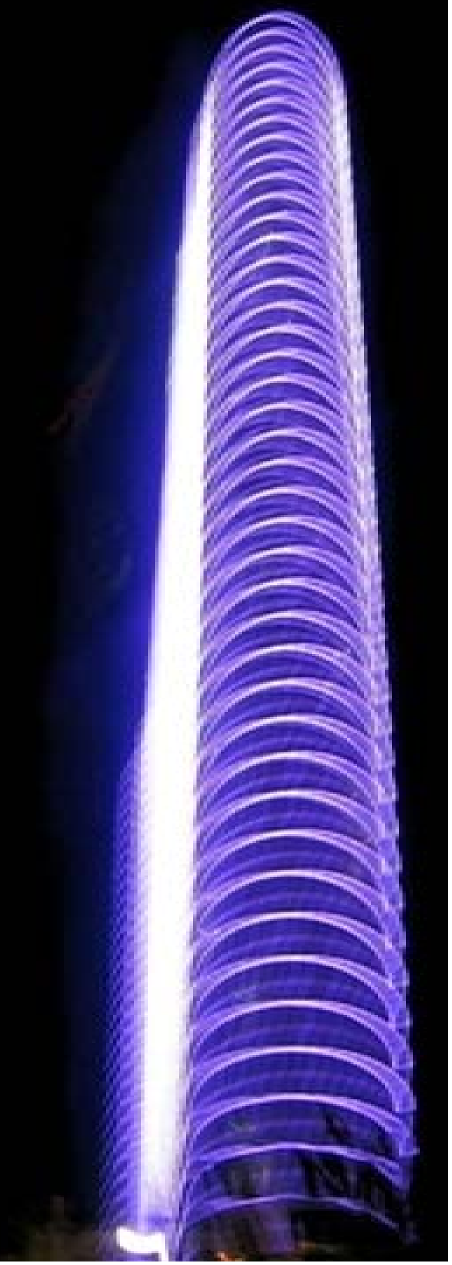
Cost of New Coupling Beams
91.7 Tons of Steel
$281,500

Construction Management Breadth

- Slabs – Concrete Takeoff

CONCRETE SLAB TAKEOFF						
Existing Slab Design				New Slab Design		
Area (SF)	Thickness	Cubic Yards		Area (SF)	Thickness	Cubic Yards
12000	8.5	315		12000	8.5	315
23000	7	497		23000	8	398
	CY/floor	812			CY/floor	712
	Floors	40			Floors	40
	Total	32,469			Total	28,494
Total Concrete Savings						
3,975 CY or 12.24%						

**In addition to concrete saves over 23,000 square feet of formwork per floor!!*

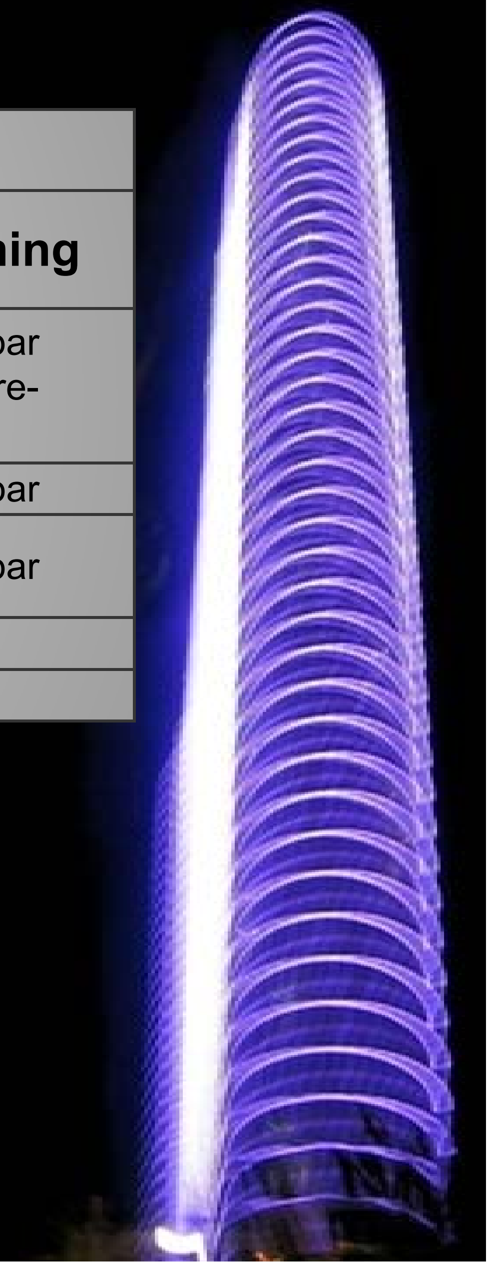


Construction Management Breadth

Schedule Impact

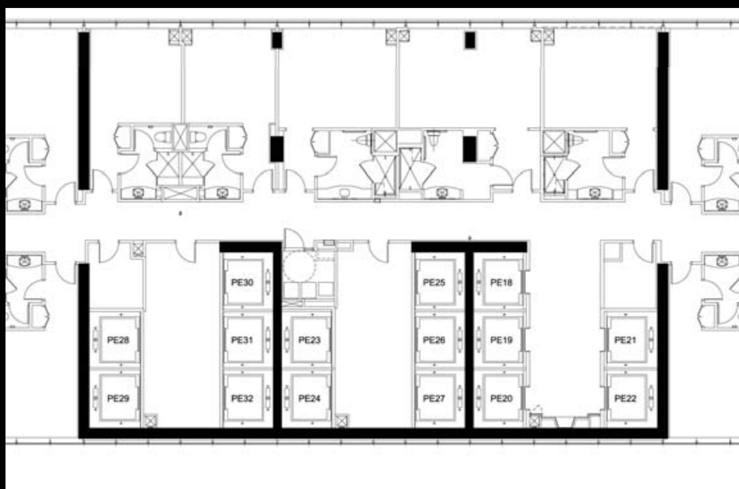
Five Day Cycle			
Day	**Columns and Walls**	**Filigree**	**Post-Tensioning**
1	Install rebar cages and forms	Install filigree plank temporary supports	Install forms and rebar Remove forms and re-shore floor below
2		Place filigree plank	Install forms and rebar
3	Pour columns and walls	Set slab rebar	Install forms and rebar
4		Set slab rebar	
5		Pour Slabs	Pour Slabs

Superstructure erection schedule reduced from 60 weeks to 40 weeks

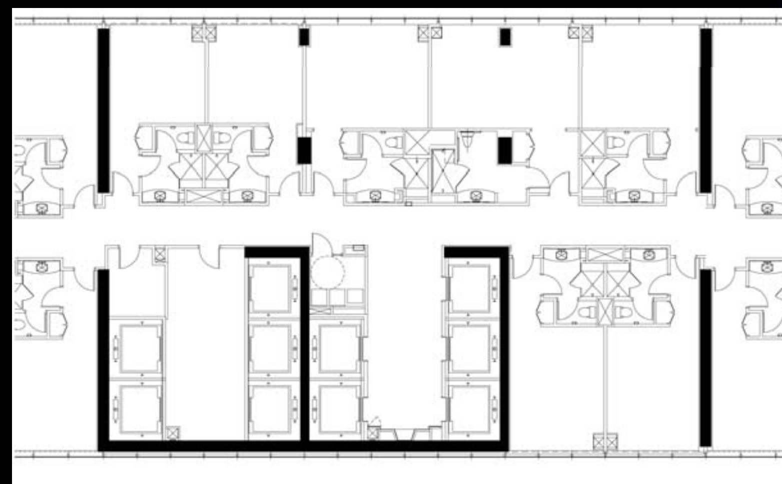


Architectural Breadth

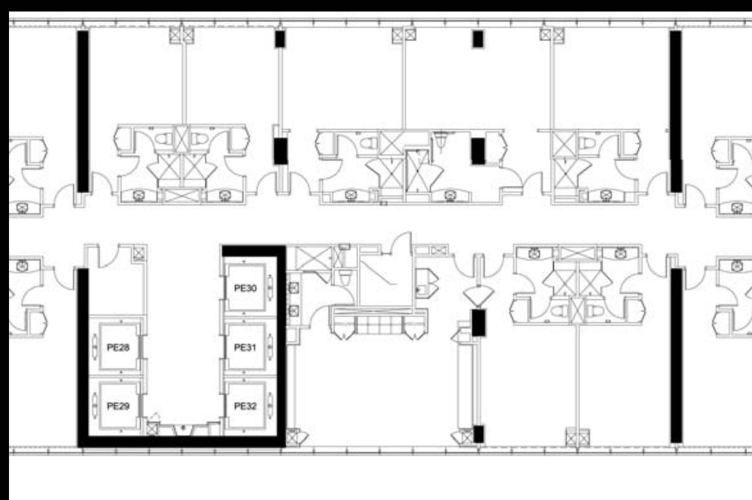
- With new core design, entire floor plan around core changes
  - Existing Floor Layout Around Core



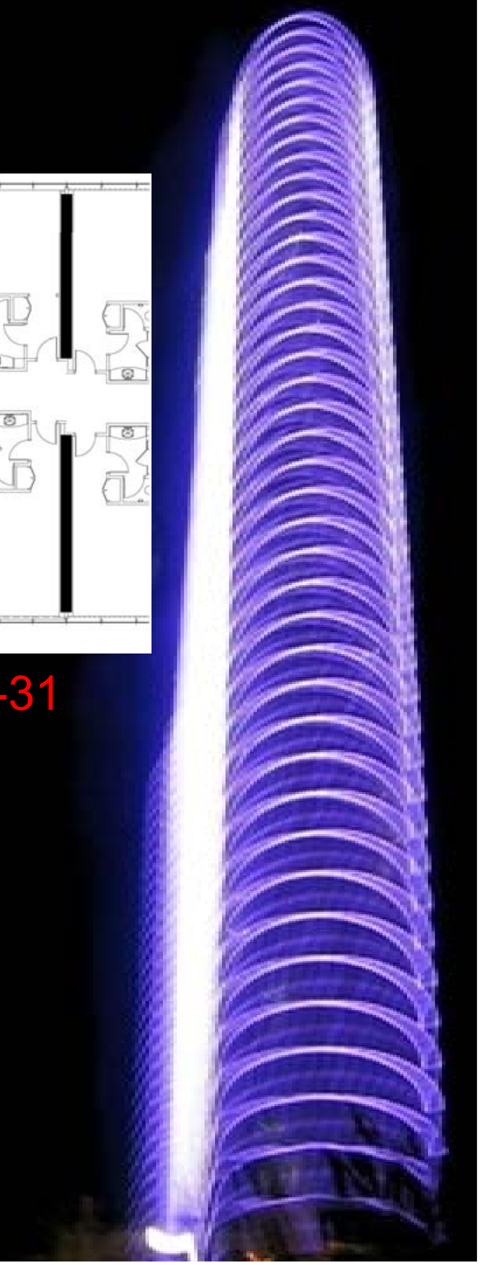
Floors 3-18



Floors 19-31

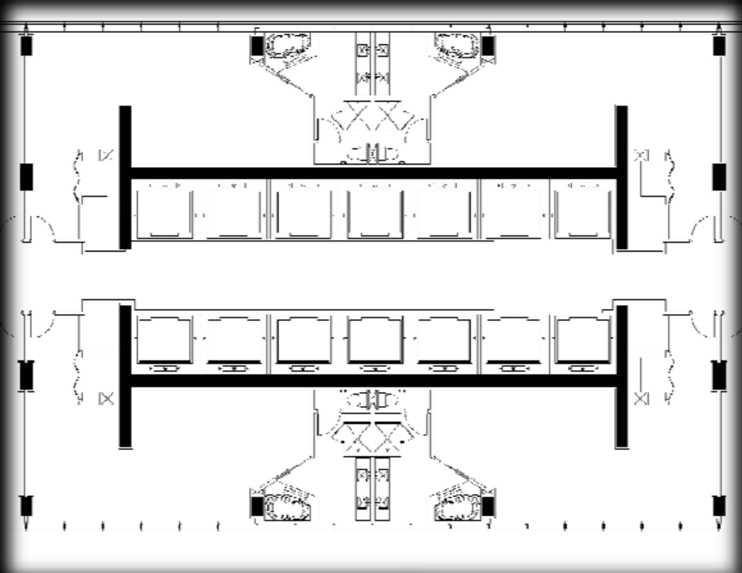


Floors 31-43

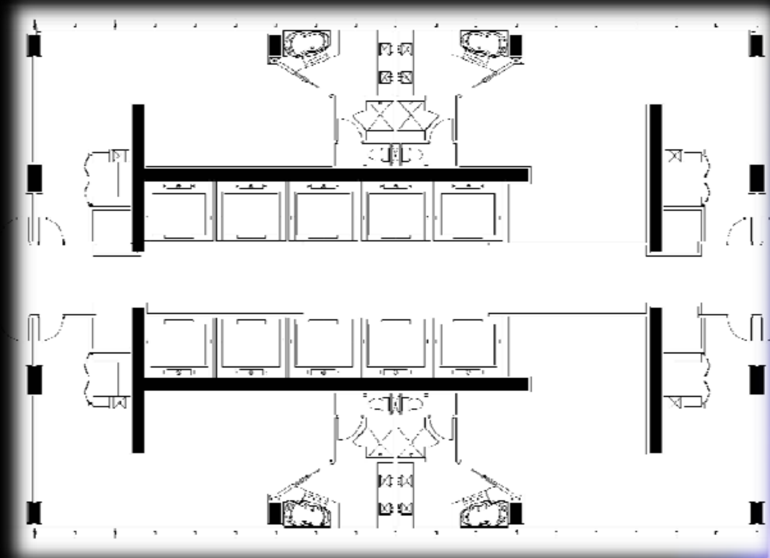


Architectural Breadth

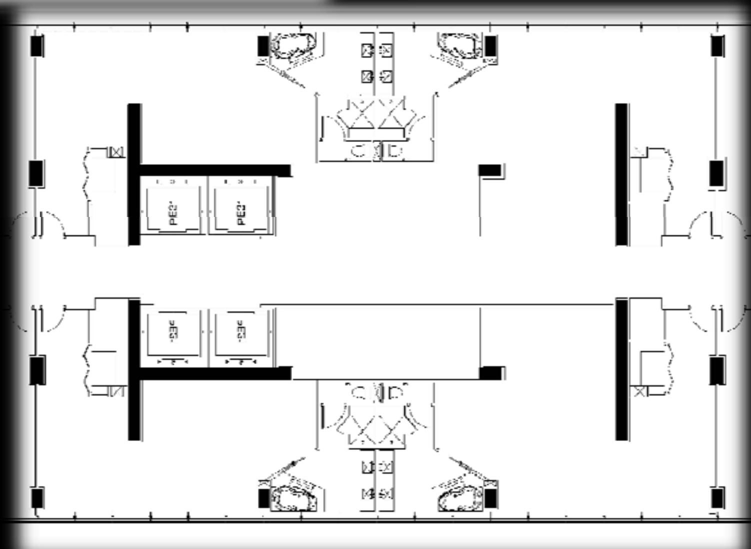
- New architectural plan around new core



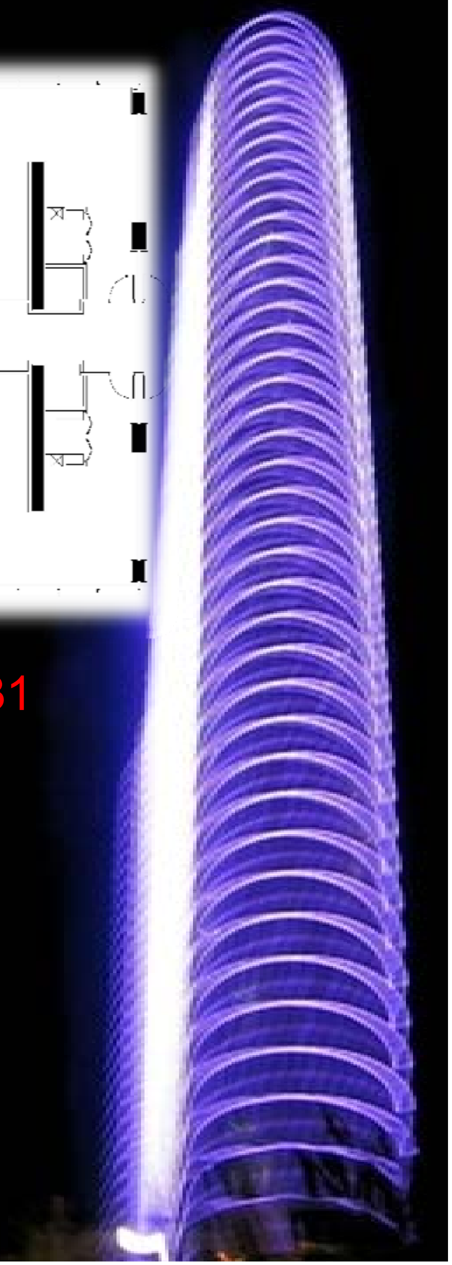
Floors 3-18



Floors 19-31

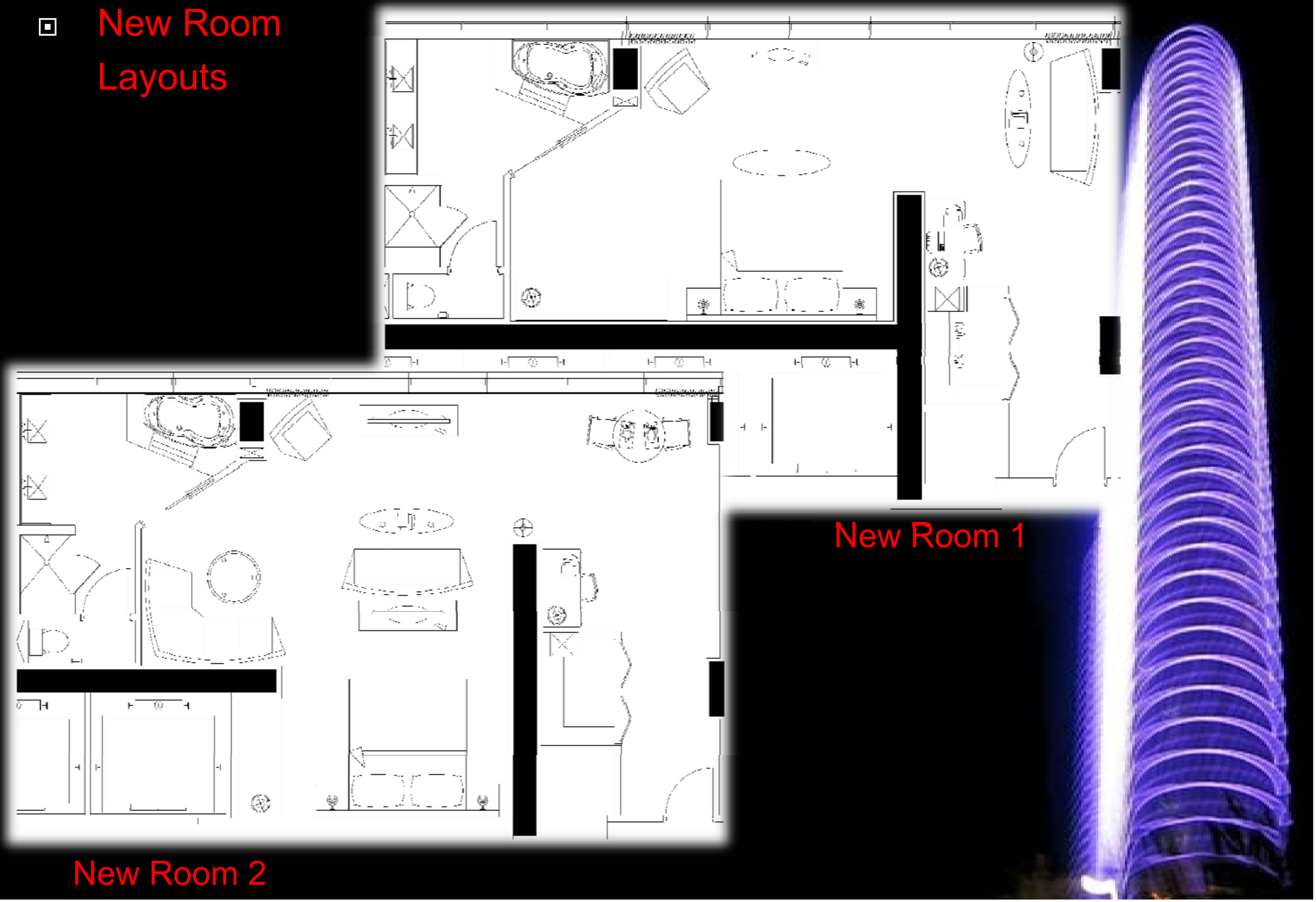


Floors 31-43



Architectural Breadth

- New Room Layouts



New Room 1

New Room 2

Conclusions and Recommendations

- Shear Wall Design
  - Reduces concrete used
  - Increases # and size of coupling beams
  - Less walls = less reinforcing, less forms, less labor
  - Reduces # classic rooms, increases luxury rooms

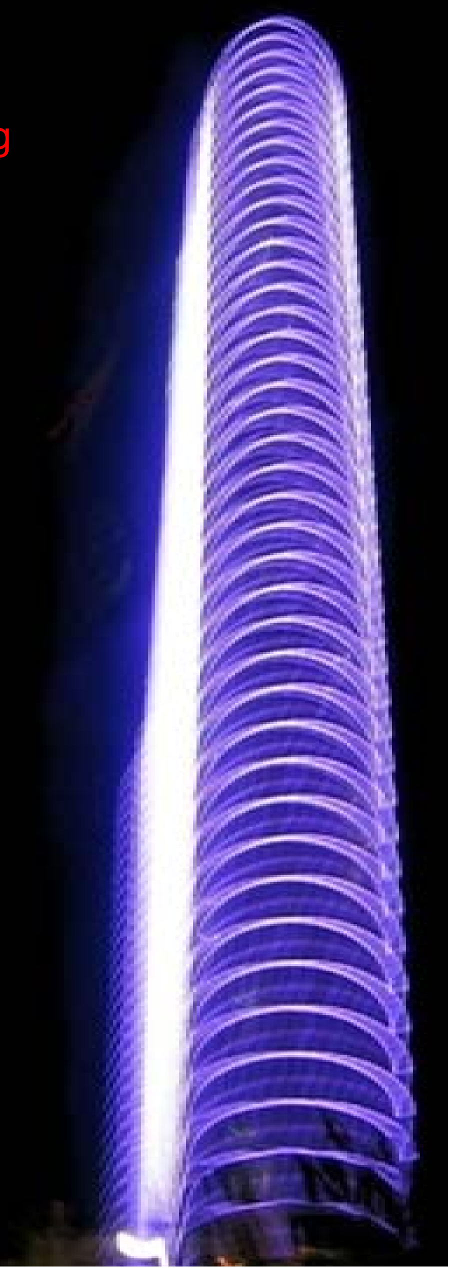
  ✓ *RECOMMEND TO USE NEW SHEAR WALL DESIGN*

- Gravity Redesign
  - Mixes filigree and post-tensioning systems
  - Reduces weight of structure
  - Reduces schedule of project

  ✘ *DO NOT RECOMMEND SYSTEM SINCE MIXING OF SYSTEMS*

Acknowledgements

- Thank You to….
  - The Harman Group for helping me obtain this project and providing structural and architectural prints
  - The Borgata for allowing me to use this project
  - Ann Yurina, at BLT/CLA Architects
  - My advisor, Dr. Memari for continuous help
  - Dr. Lepage for last minute ETABS help
  - The rest of the AE faculty
  - Fellow AE’s for help and support



Questions?

Schematic Foundation Plan