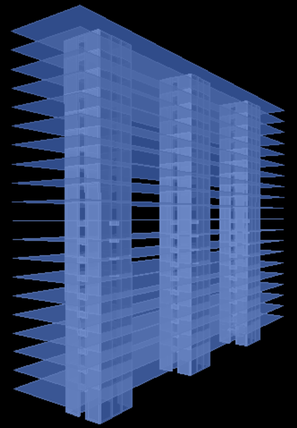
Southwest Student Housing Building

1000 Apache Boulevard East, Tempe, Arizona

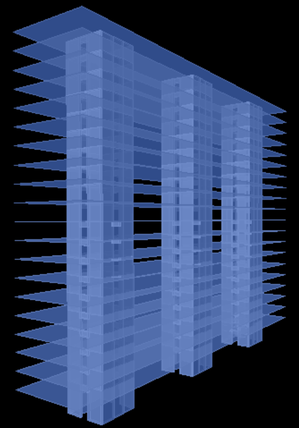
Ksenia Tretiakova
Structural Option

Faculty Adviser: Dr. Andres Lepage



- Building Background
- Building Structural System
- Problem Statement
- Proposed Solution
- Structural Investigations
- Architectural Impact
- Sustainability Study
- Conclusion

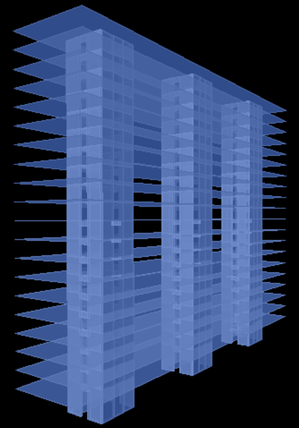
Building Background



- Client: Arizona State University
- New 20-story apartment building
- Overall height: 208 ft
- Total area: 260,000 ft^2
- Estimated total cost: $37.5 million
- Projected construction time: 177 days (9 months)

Site Map

Building Background

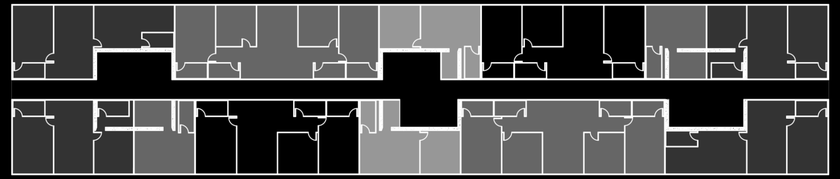


Unique Features

- Modular
- Uses prefabricated assemblies
- Slip-formed concrete cores
- No columns
- Erected using Lift Slab Construction

  - L'Ambiance Plaza, 1987

Typical Floor Plan



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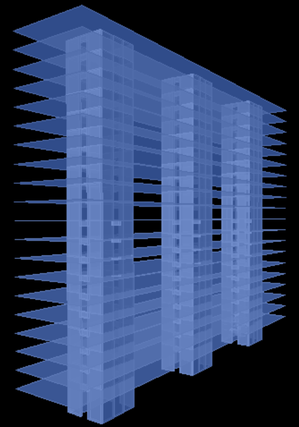

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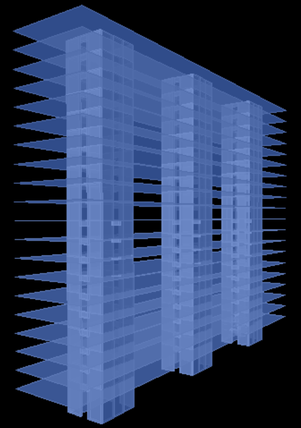
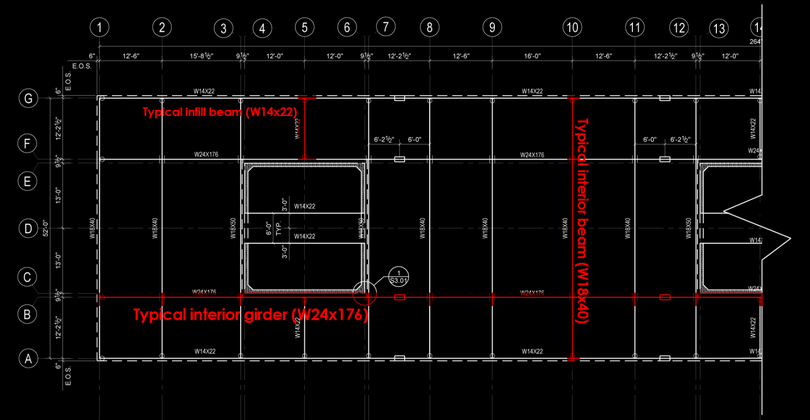
Lift-Slab Construction

Building Structural System



- Mat Foundation
  - Soil conditions
- Floor System
  - Structural steel framing
  - 3" metal deck
  - 3-1/4" lightweight concrete topping

Structural Framing Plan



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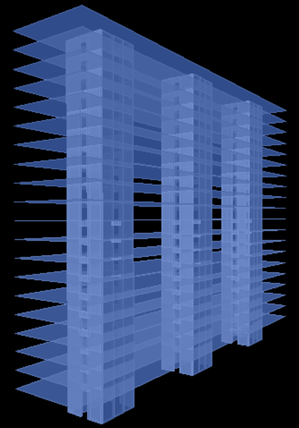


- Gravity and Lateral system

Gravity:

Load Type	Load Value (psf)
Construction Dead Load	59
Superimposed Dead Load	15
Live Load	80
Façade Load	15
Snow Load	0

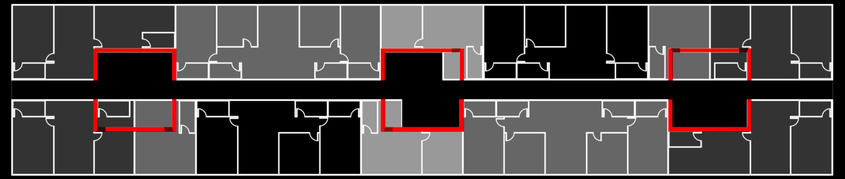
Lateral:

V_{base} = 235k

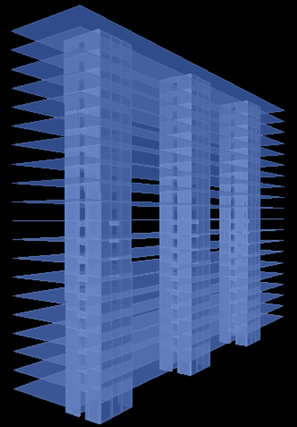
V_{wind} = 565k

Maximum drift = 2.74 in (h/400 = 6.24 in)

(3) 25' x 25' Concrete Cores



Problem Statement



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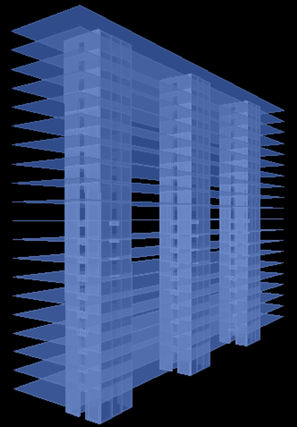

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  - How would the connection of the floor system to the core need to change?

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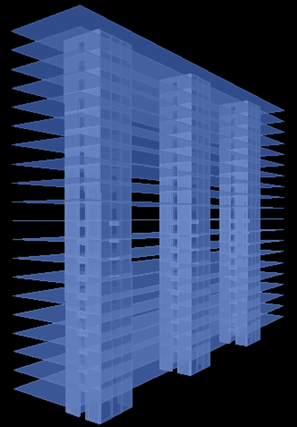

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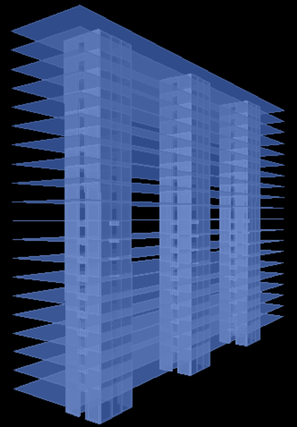

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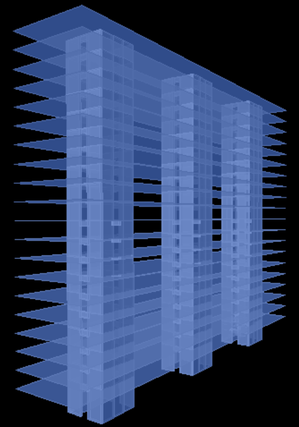

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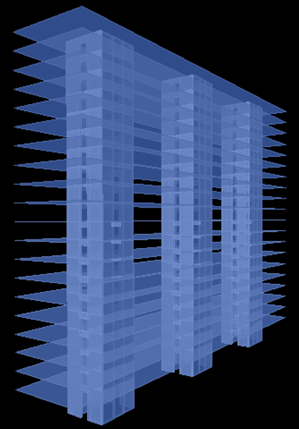
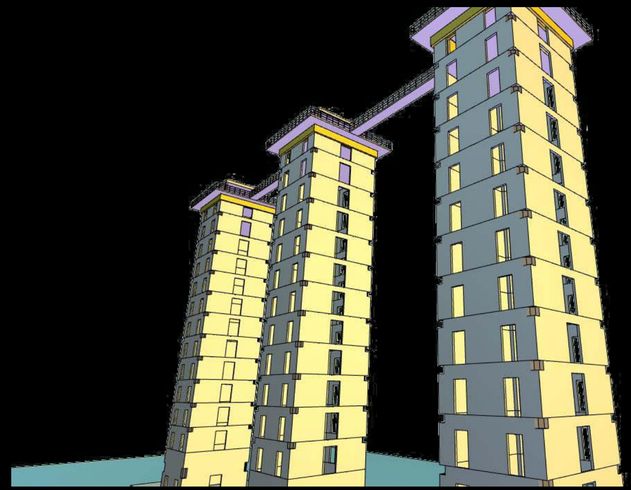
- How easily could it be redesigned for higher seismic loads?
  - How would the connection of the floor system to the core need to change?
- How does the construction cost fluctuate for more extreme loading conditions?
- What effect would the redesign have on the floor plan?
- How easily can this type of building attain a LEED Certification in a cost-effective way?

Proposed Solution

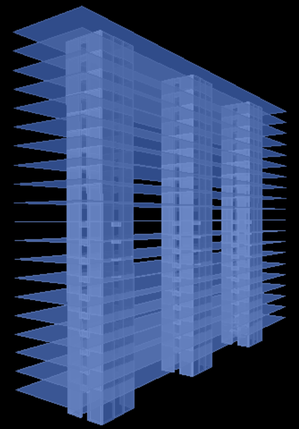


- Relocate to SDC D
  - St Louis, Missouri
- Investigate ways to transfer diaphragm shear to the cores
- Cost analysis
- Architectural evaluation
- Sustainability study

Core Openings in the Original Design



Structural Investigations



- New design loads:

Gravity Loads		
Construction Dead Load	59	psf
Superimposed Dead Load	15	psf
Live Load	80	psf
Façade Load	15	psf
Snow Load	20	psf
Base Shear	1001.4	kips

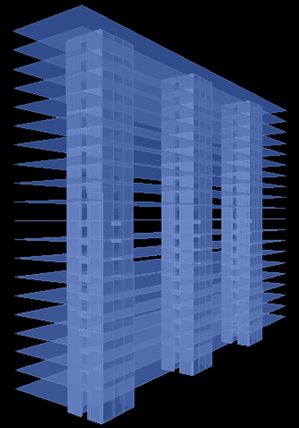
- Special reinforced concrete shear walls
- Assumption: no extreme torsional irregularity (ASCE 7-05, 12.2.5.4)

- $C_{s,new}$ = 0.027
- $W_{bldg,new}$ = 24,349 kips

- Trial sizing: 12" , 16" and 18" walls
  - Used 16" walls for building weight

- Shear check: t_{min} = 9.26 in

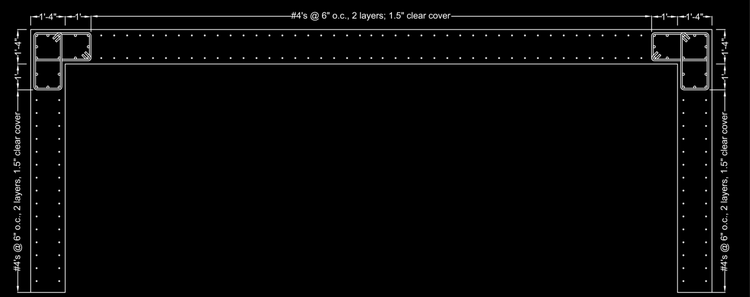
Structural Investigations



Core Design

- Trial wall thickness = 16”
- Minimum shear reinforcement
  - V_c = 2678k >> V_{base} = 1001k
- Minimum moment reinforcement
- Boundary elements
- Maximum compressive stress = 0.253f’$_c$

- Reinforcement details:



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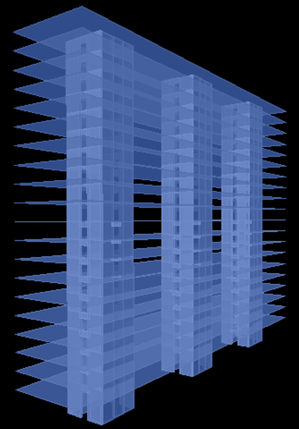

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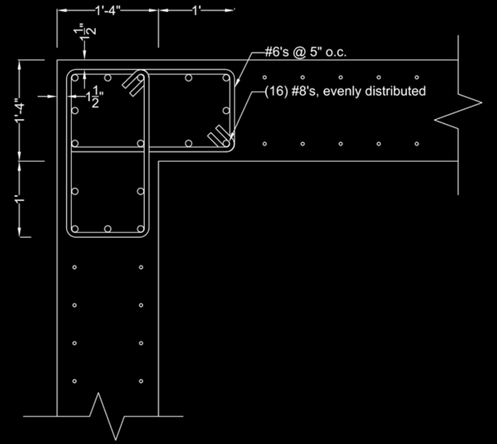
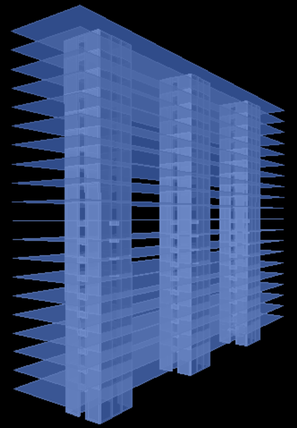




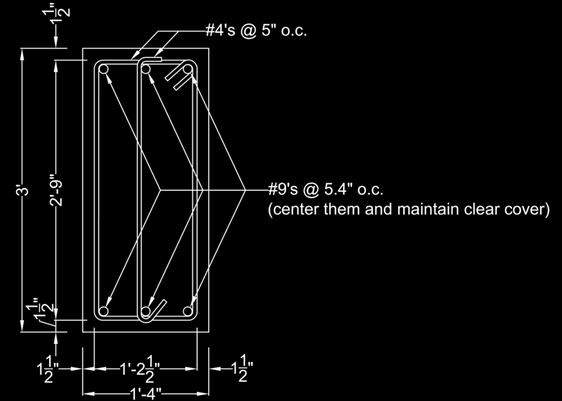
Core Design

- Coupling beams
  - Shear from ETABS model:

$V_{max,model\ (3rd\ floor)} = 130.7$ kips

$V_{coupling\ beam\ design} = 158$ kips

- Reinforcement details:



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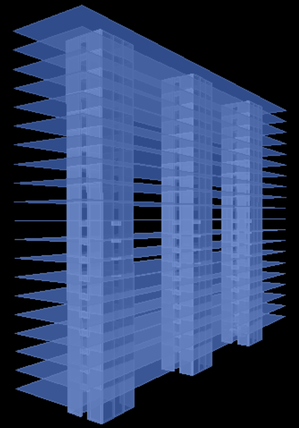
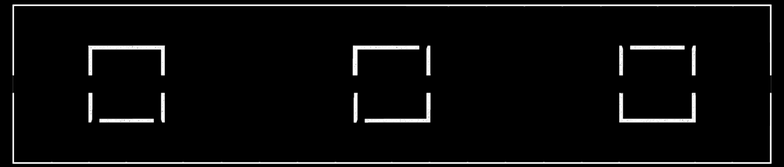


Core Design

- Modeling
  - 3 models (different core layouts)
    - **Original design**
    - Option 1(minimal openings)
    - Option 2 (consolidated openings)

Core Shapes



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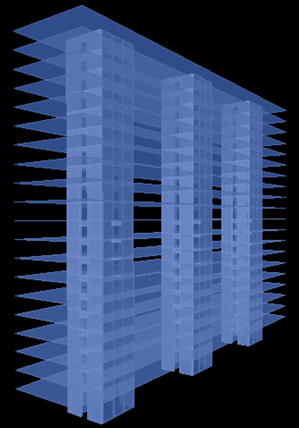

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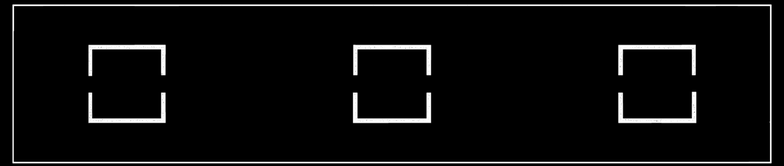

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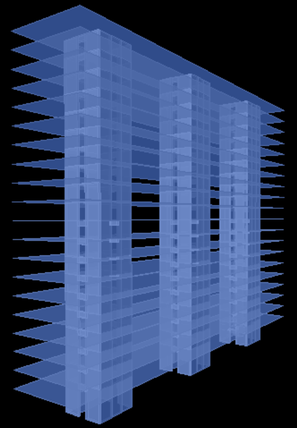

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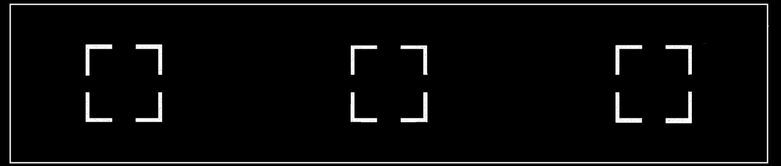

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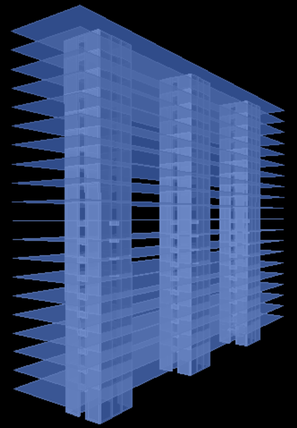

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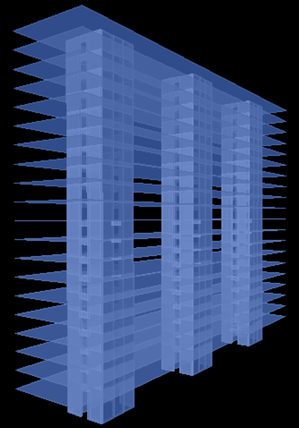
ETABS Outputs

Design	Original	Option 1	Option 2
Max Deflection (in.)	6.126	6.126	9.737
Min Deflection (in.)	-0.455	-0.888	-2.555
Mode 1 (sec)	3.943	2.167	2.783
Mode 2 (sec)	3.521	2.025	2.486
Mode 3 (sec)	3.319	1.797	2.332

Structural Investigations



Floor System Design

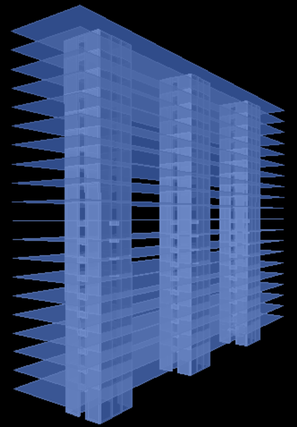
- Focus: floor-to-core connection
  - Shear transfer
- Complexity
  - Coupling beams
  - Boundary elements
  - Construction method

- 2 potential designs:
  - "Steel Collar" Design

    Shear goes directly from diaphragm to core via shear studs embedded in the core
  - "Drag Strut" Design

    The beams running along each core act as collector elements, shear transfer is from beams to core via welds on elements embedded in core

Structural Investigations



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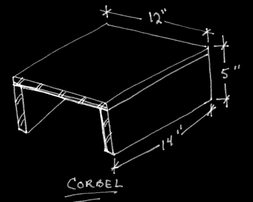

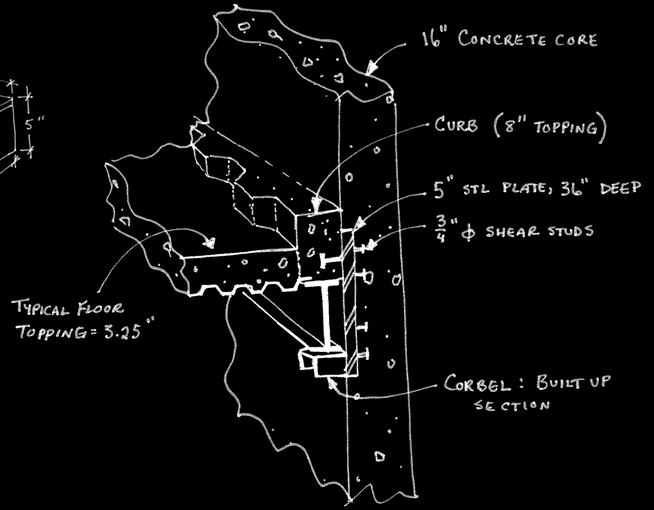

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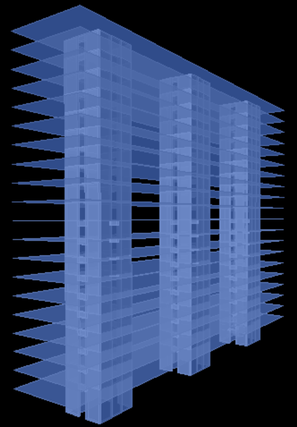

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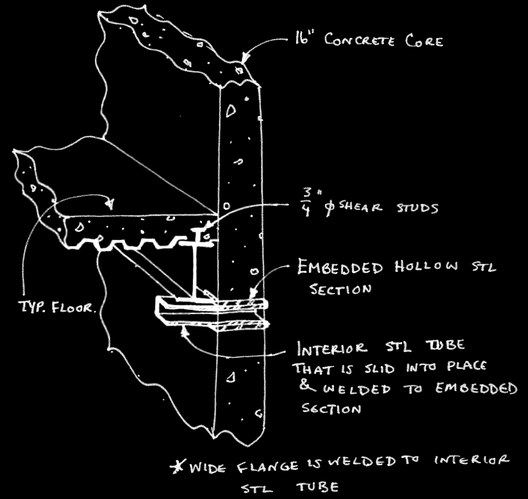

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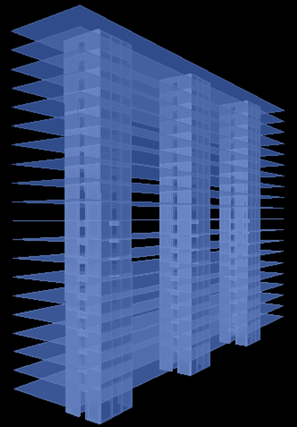


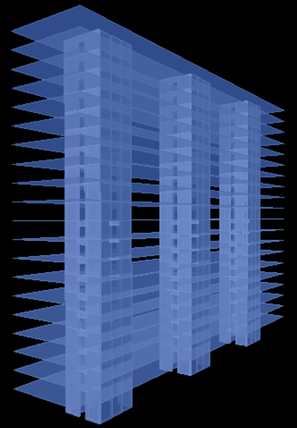
Cost Evaluation

- Used bare material costs for evaluation

Bare Material Costs			
Item	**Original Design**	**Option 1**	**Option 2**
Concrete	113373	247340	216553
Reinforcement	74385	381027	432258
Welds	0	1080	1080
Shear Studs	0	70553.6	6364.8
Other Steel	0	2069809.2	2069809.2
Total ($)	187757	2769810	2726064
Difference from Origin	0	2582053	2538307

- About the same for both options
- Additional 8% of total construction cost

Architectural Impact



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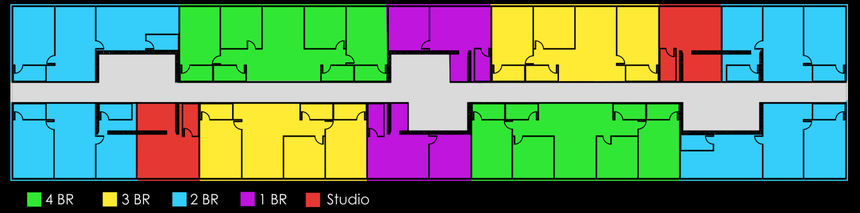
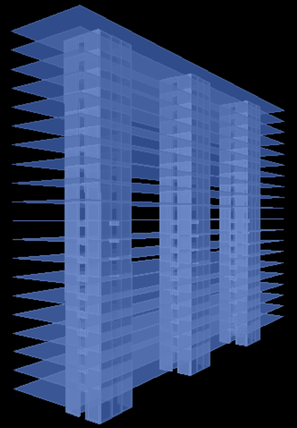


- Advantages
  - Easy access to cores
  - Regular
  - Modular
- Disadvantages
  - Numerous core penetrations
- Patterns
  - Bathrooms line the corridor

Architectural Impact



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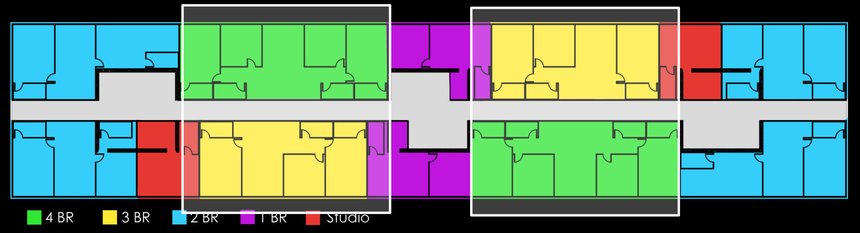

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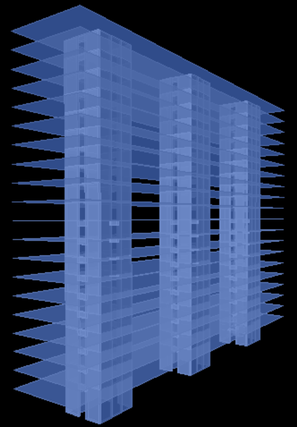
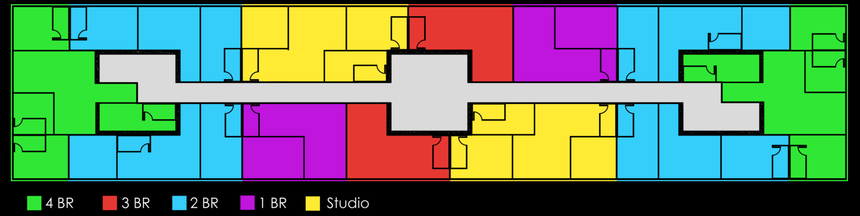
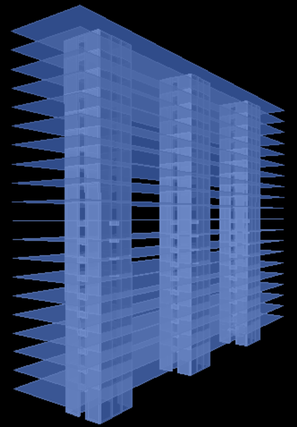


Option 1

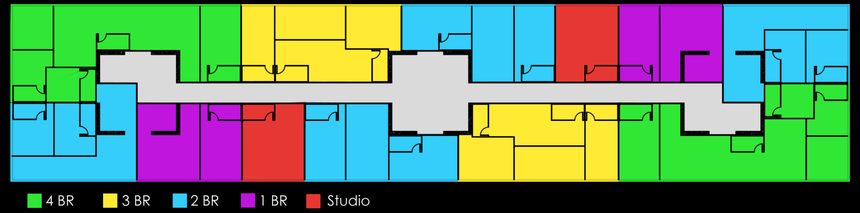


- Advantages
  - No core penetrations
  - More usable area
- Disadvantages
  - Not as regular
  - Bathrooms are not as stacked

Architectural Impact

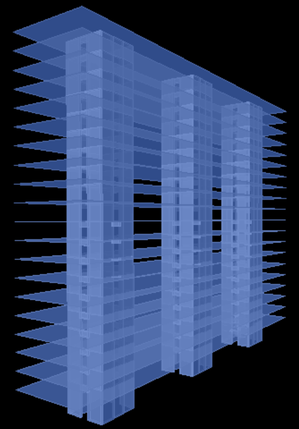


Option 2



- Advantages
  - Easy access to cores
  - Modular
  - More usable area
  - Bathrooms are more stacked
- Disadvantages
  - Core penetrations

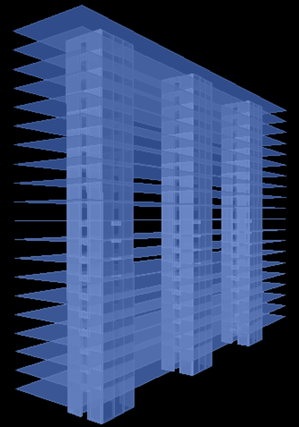
Sustainability Study



Goal

- Attain a minimum of LEED Certified status with minimal, if any, cost investment

  - LEED Certified status requires a minimum of 40 points

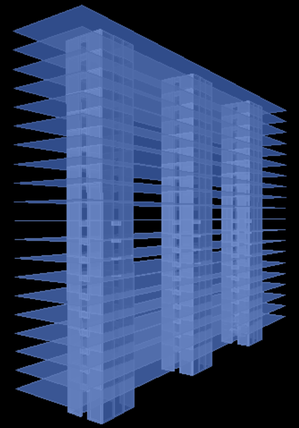


LEED Point Evaluation

- Current design = 20 points

- Additional easily attainable points = 21
  - 3 of the 21 credits require money
    - Sheltered bike racks for 15% of residents
    - Landscaping to protect, restore and shade the site

Sustainability Study



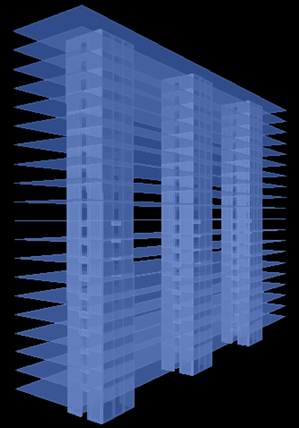
LEED Point Evaluation

- Bike racks (1 credit)
  - Estimated cost at about $\$70/ft^2$
  - Estimated area needed = $450\ ft^2$
- Total cost = $35,000
  - (0.1% of total building cost)

- Current design = 20 points

- Additional easily attainable points = 21
  - 3 of the 21 credits require money
    - **Sheltered bike racks for 15% of residents**
    - Landscaping to protect, restore and shade the site

Sustainability Study



LEED Point Evaluation

- Landscaping (2 credits)
  - Total cost = $200,000

(0.5% of total building cost)

Total estimated cost for 3 credits:

$235,000

(0.6% of total building cost)

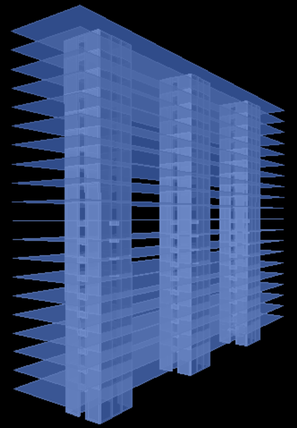
- Current design = 20 points

- Additional easily attainable points = 21
  - 3 of the 21 credits require money

- Sheltered bike racks for 15% of residents

- **Landscaping to protect, restore and shade the site**

Conclusion



Structural, Architectural, Cost

- 8% more expensive (bare material) in SDC D
- Complicated connections
- Viability:
  - None. Extreme torsional irregularity.

    Torsional amplification factor ≈ 2.5 for Option 1

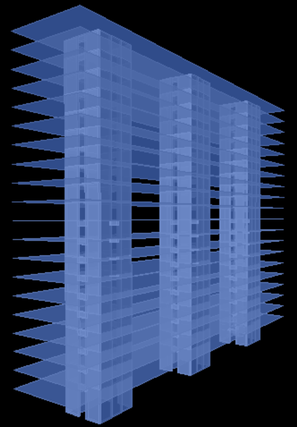
    Peer review?
  - Architecturally viable

Sustainability

- Can easily attain LEED Certified
  - Requires:

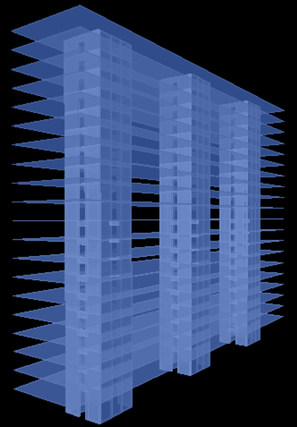
    Initial time investment during preconstruction

    Monetary investment of 0.5 - 0.6% of total cost

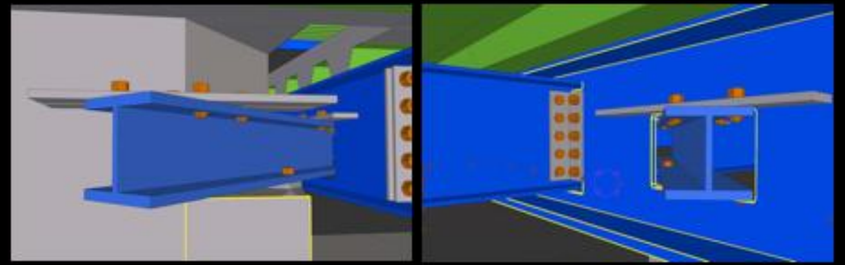


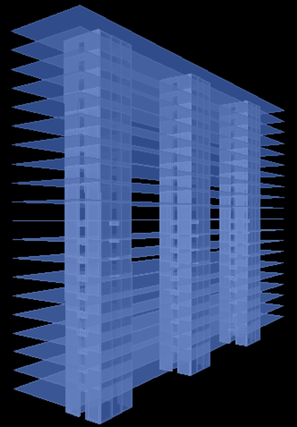
- Building Background
- Building Structural System
- Problem Statement
- Proposed Solution
- Structural Investigations
- Architectural Impact
- Sustainability Study
- Conclusion

Questions or Comments?



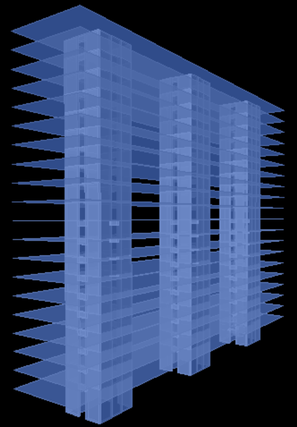
Core Corner Details



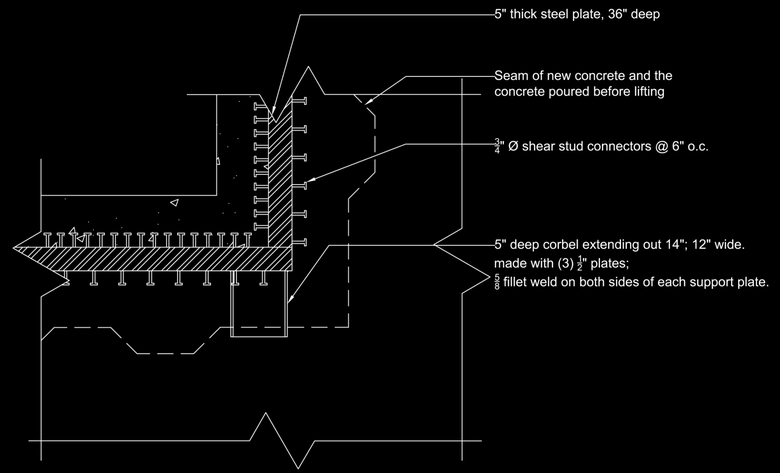


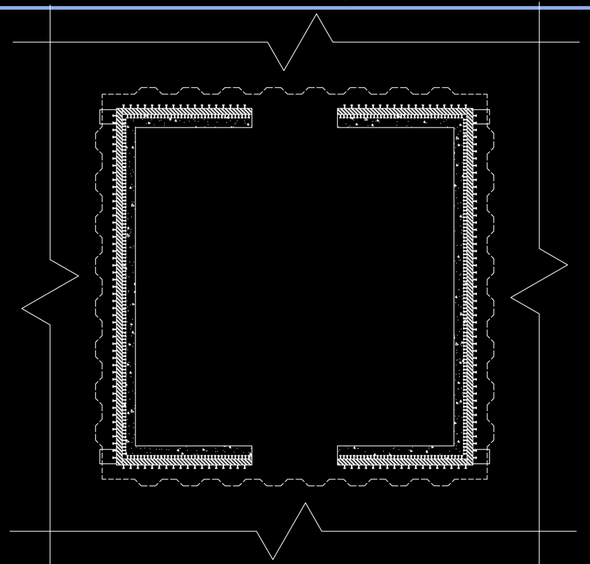
Masses Modeled in ETABS

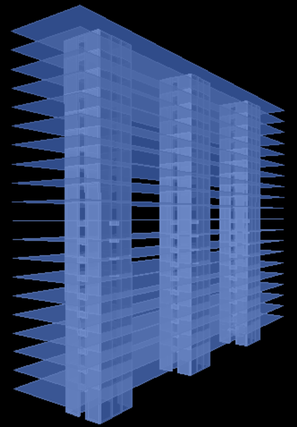
Model Masses	
Roof	1.73E-06 k-sec2/in2
Typical Floor	2.57E-06 k-sec2/in2
First Floor	3.16E-06 k-sec2/in2



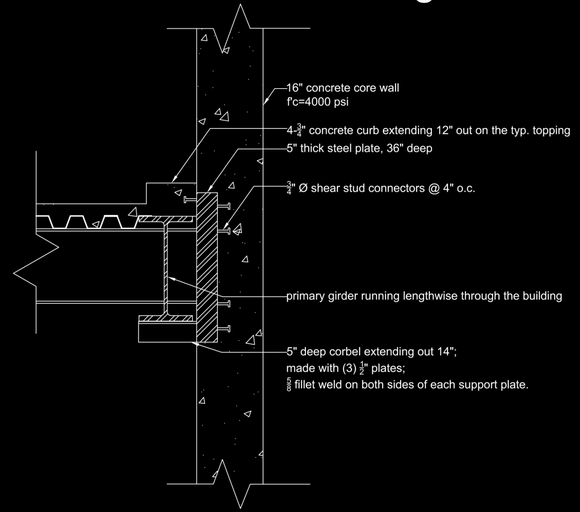
Steel Collar Design

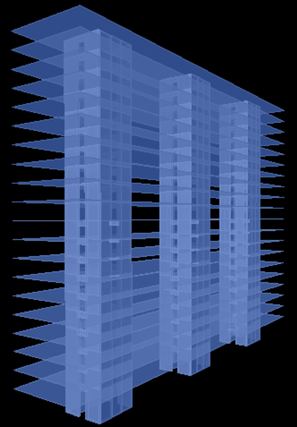




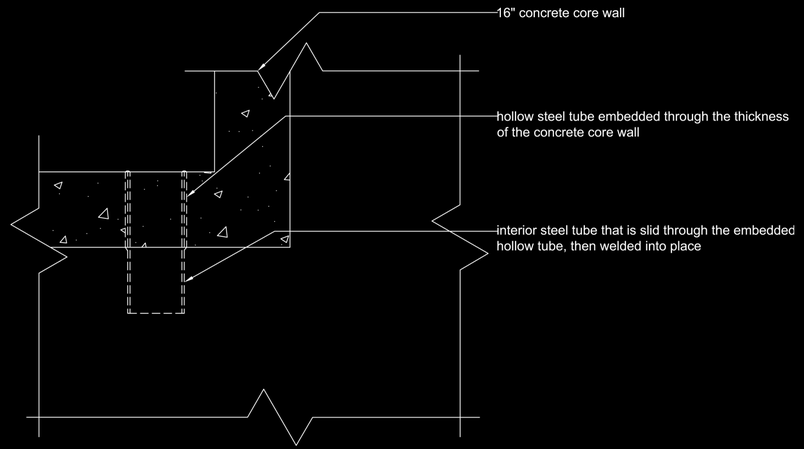


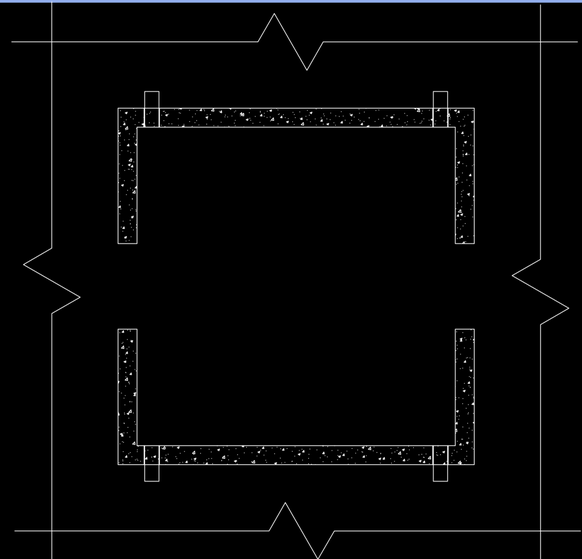
Steel Collar Design

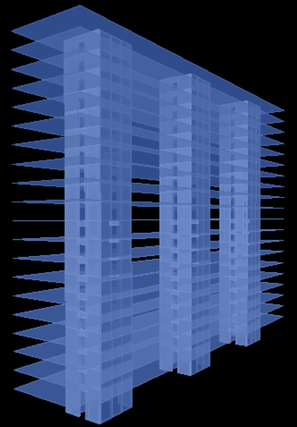




Drag Strut Design







Drag Strut Design