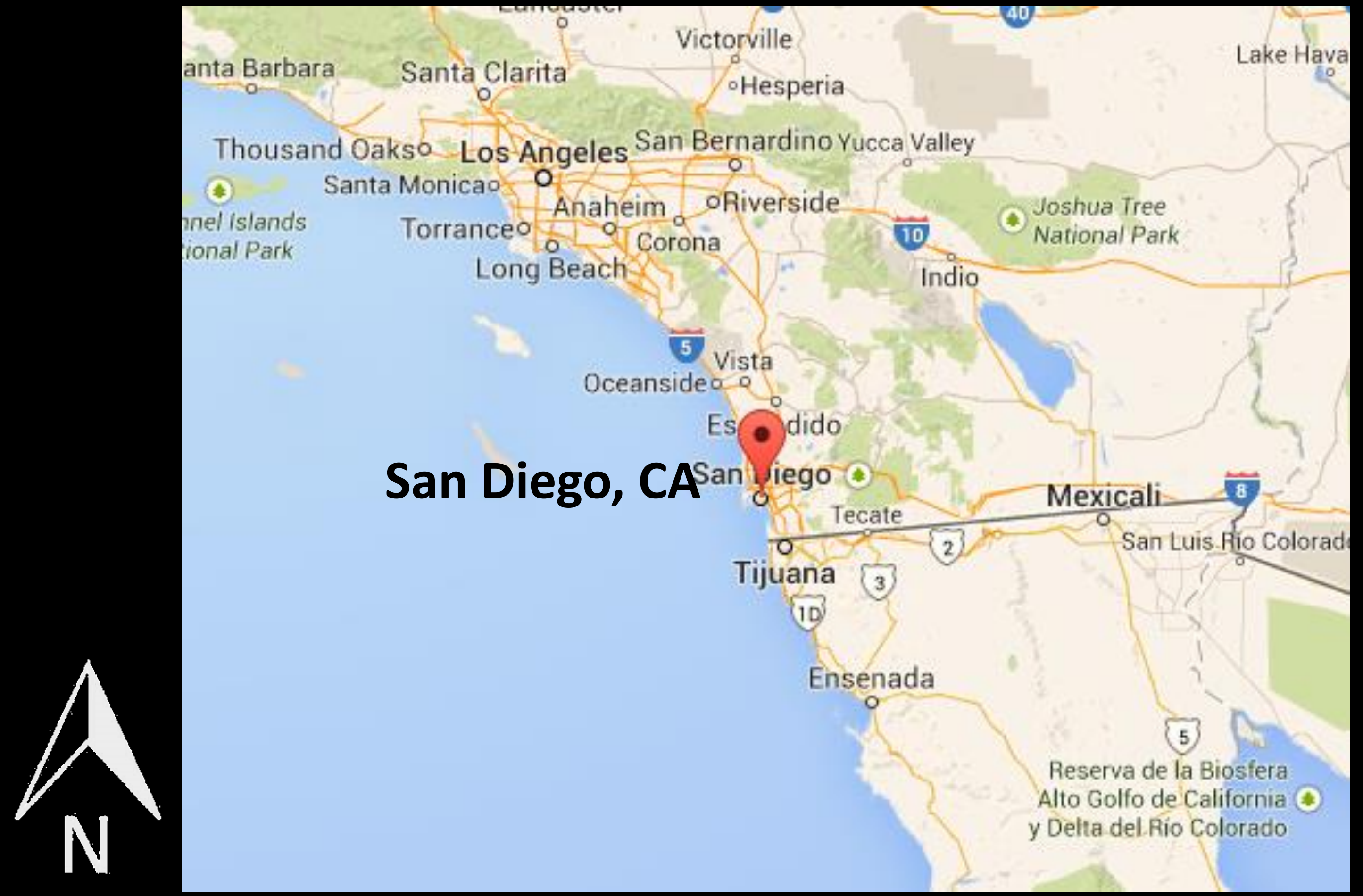
La Jolla Commons
Phase II Office Tower

San Diego, California

Alyssa Stangl | Structural Option
Faculty Advisor | Dr. Hanagan

Building Introduction

- Location | San Diego, California – SDC D
- 13 Stories + Penthouse | 198' – 8"
- 2 Levels | Underground parking
- 462,301 GSF
- Design-Bid-Build
- Construction Dates | April 2012 – May 2014
- Building Cost | $78,000,000



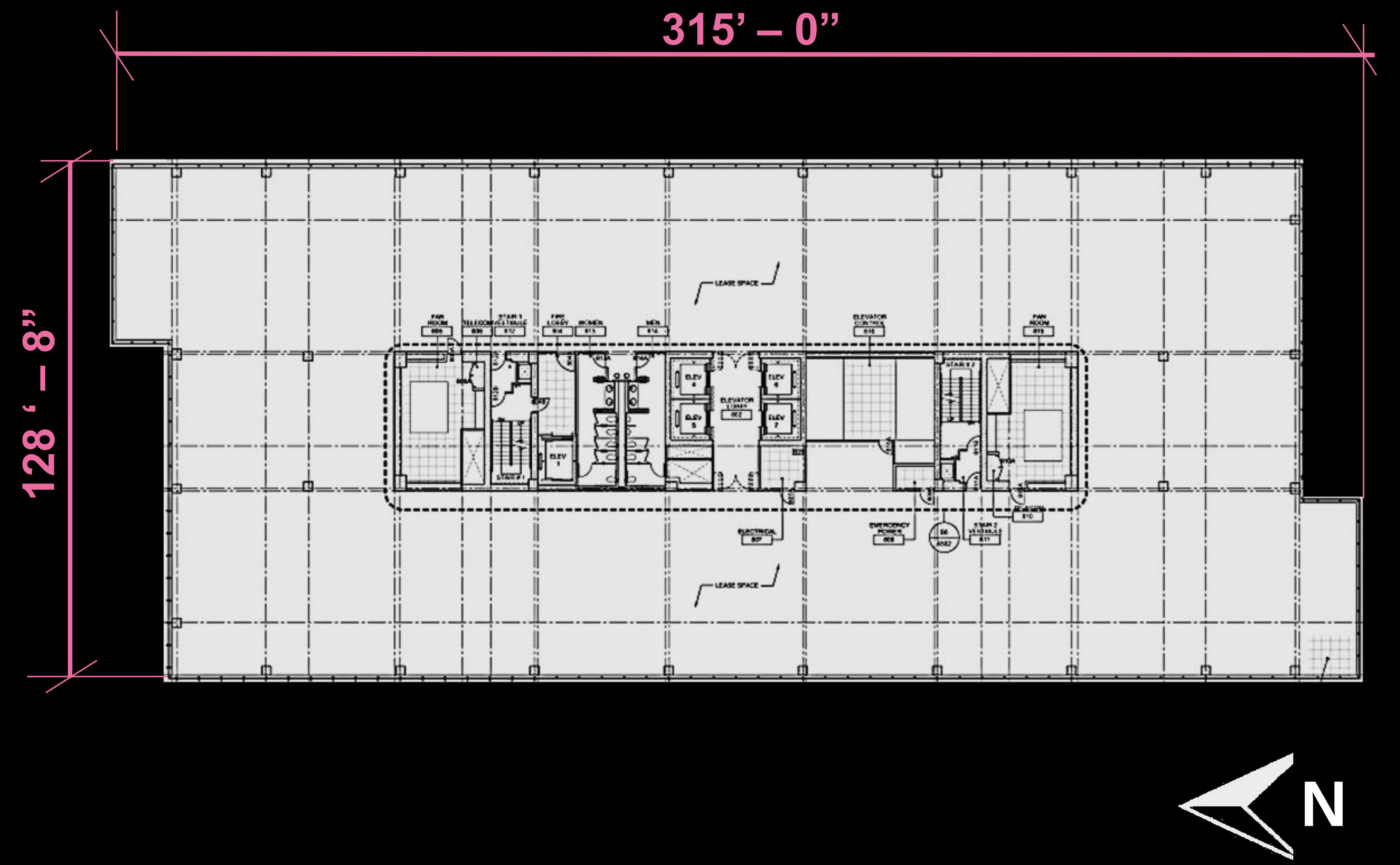
Project Team

- **Owner** | Hines
- **Tenant** | LPL Financial
- **Architect** | AECOM
- **Structural Engineer** | Nabih Youssef Associates

- **Building Introduction**
- Design Scenario and Proposed Solution
- Gravity Redesign
  - Preliminary Vibrations and Layout
  - Beam and Column Designs
  - Final Vibrations Analysis
- Lateral Redesign
  - Layout
  - Moment Frames
  - Shear Walls
- Architecture Breadth
- Construction Breadth
- Conclusions

Architectural Overview

- Large open floor plans
- Office use only
- Similar architecture to LJC Tower I
- 198’-8” height limited by FAA
- LEED-CS Gold & NetZero



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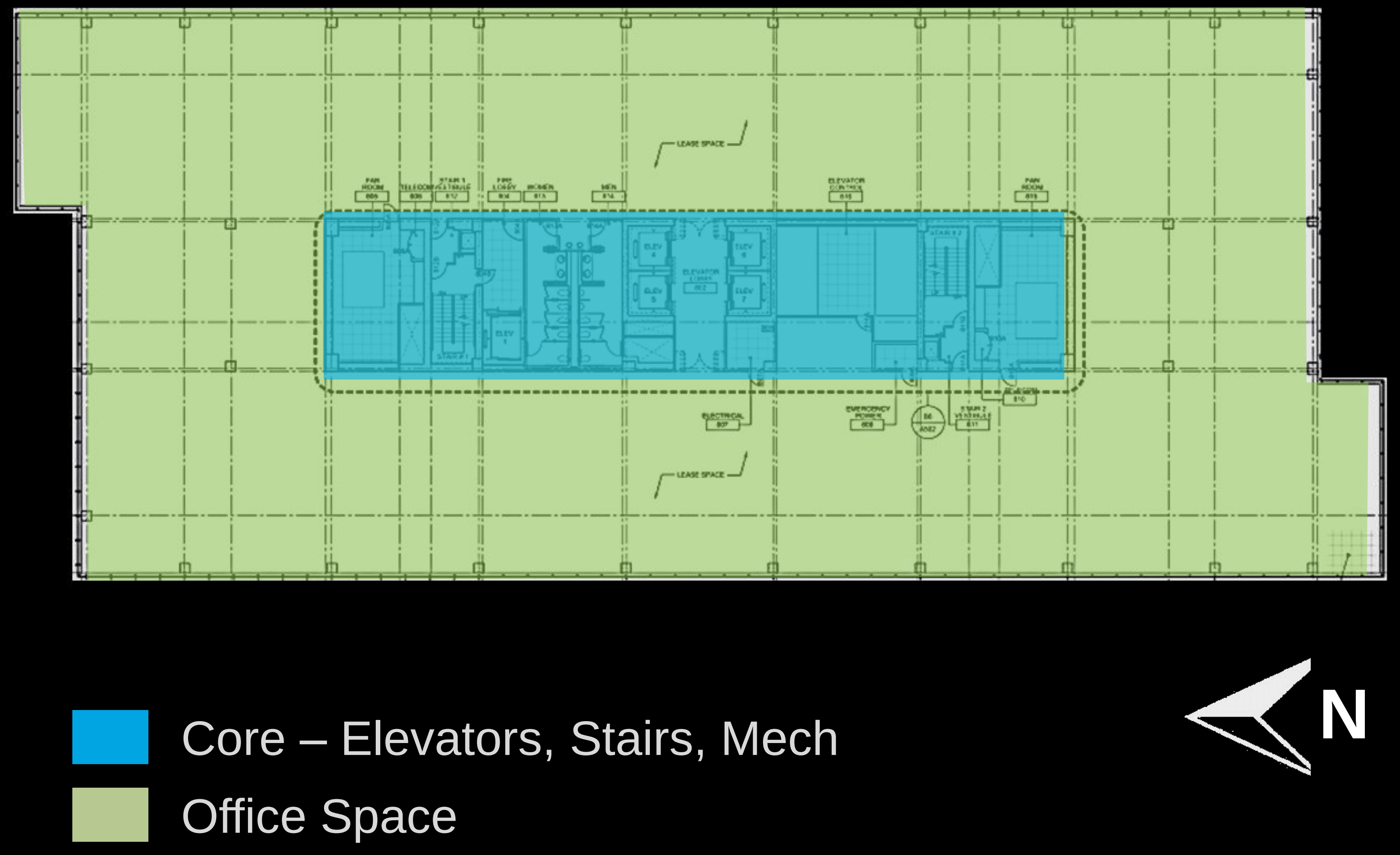

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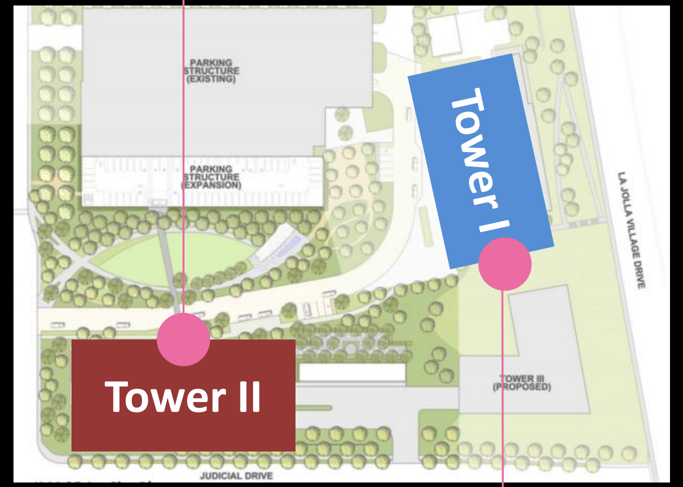

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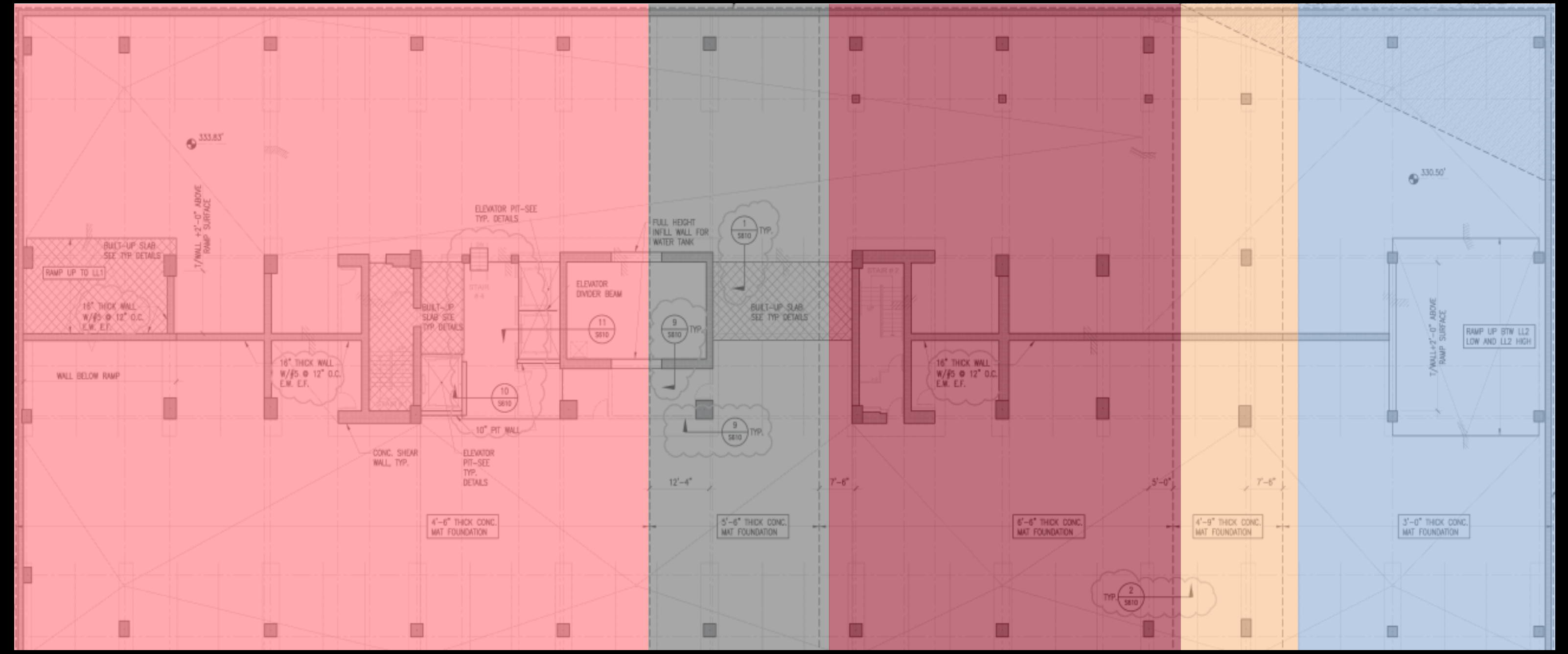
Existing Structural Overview

- Gravity System
  - **Mat foundation**
  - Floor System
- Lateral System
  - Shear Walls
  - Collectors



4'- 6" Thick
5'- 6" Thick
6'- 6" Thick
4'- 9" Thick
3'- 0" Thick

N

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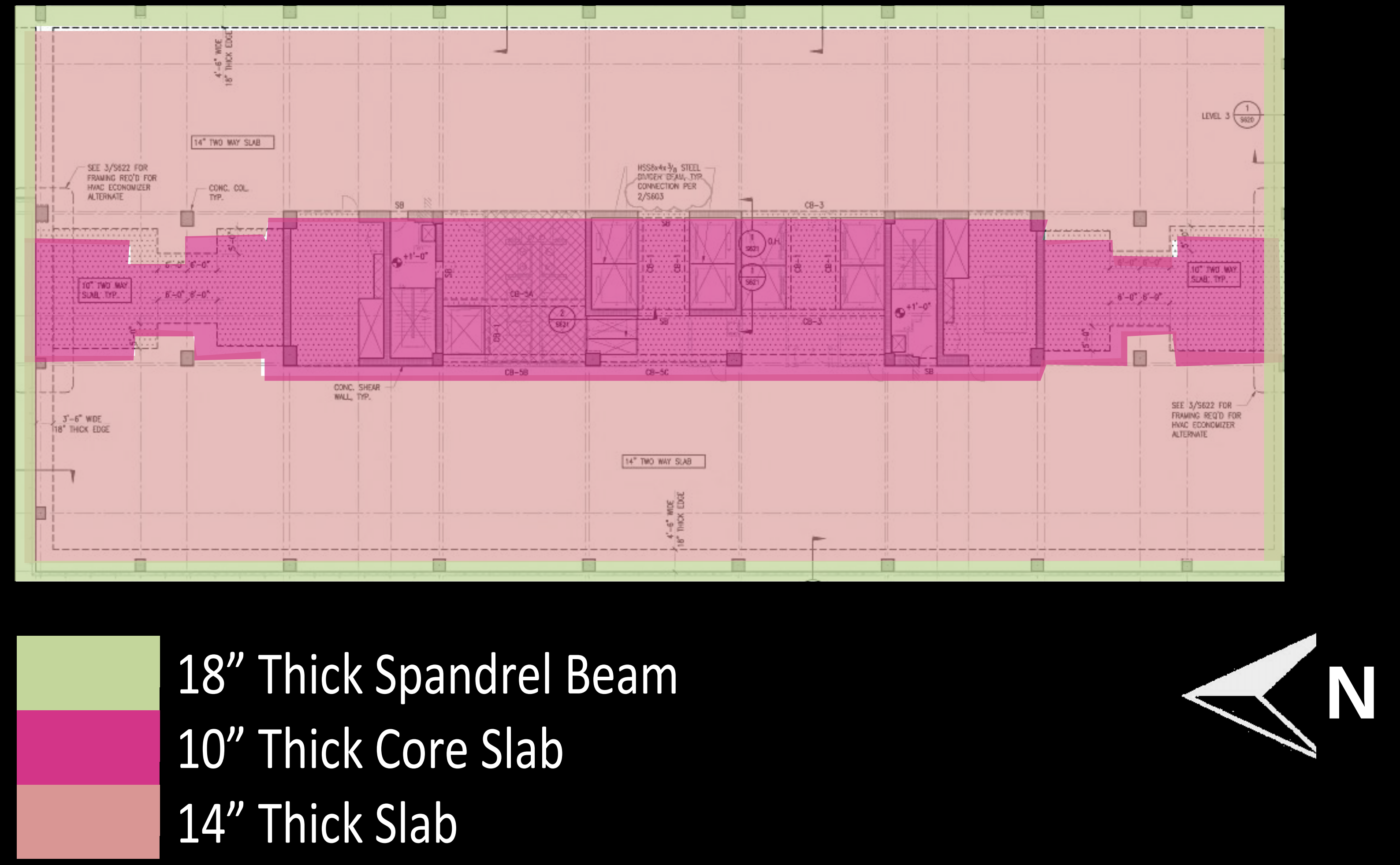
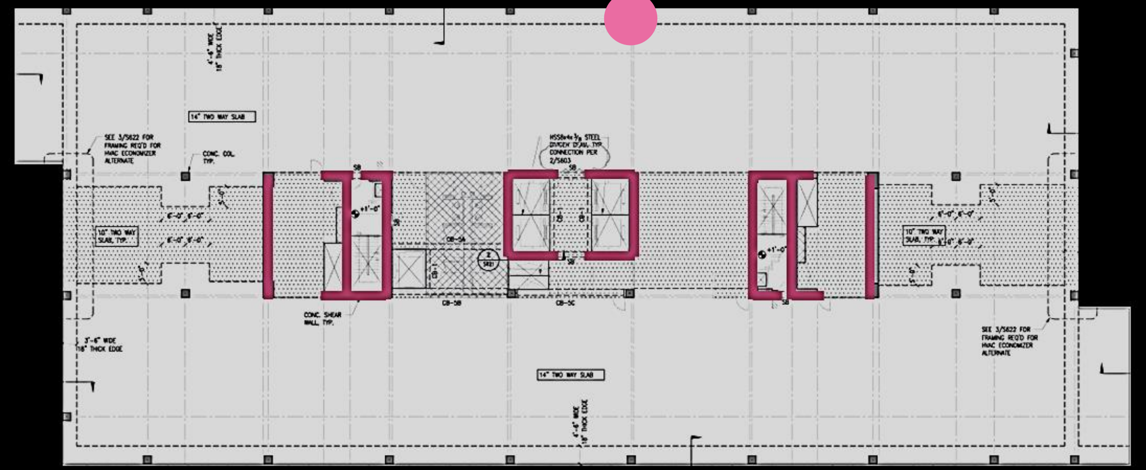
Existing Structural Overview

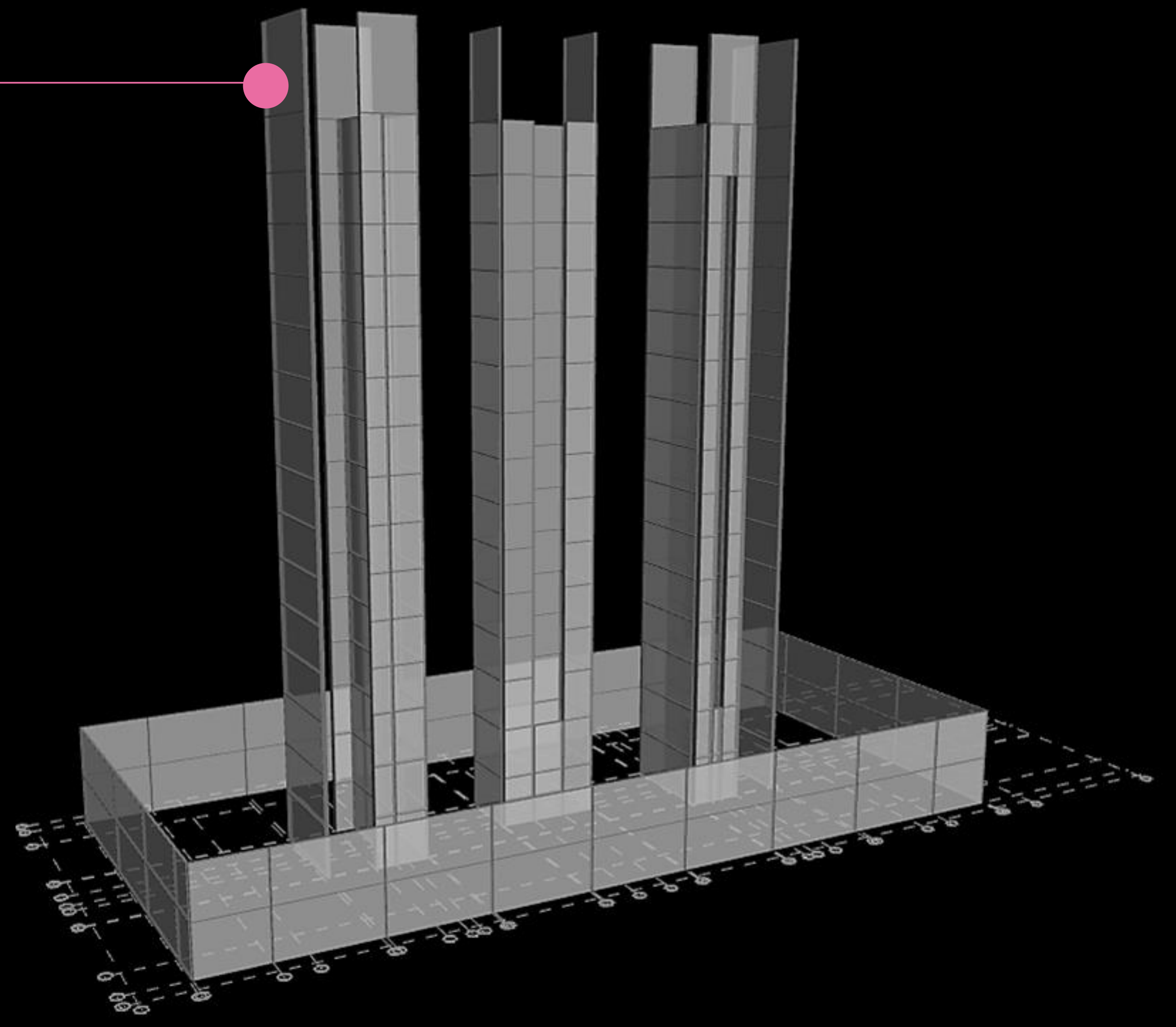
- Gravity System
  - Mat foundation
  - **Floor System**
    - Two-Way, Flat Plate Concrete Slab
    - 10” – 14” Thickness
    - 18” Spandrel Beam
- Lateral System
  - Shear Walls
  - Collectors



Existing Structural Overview

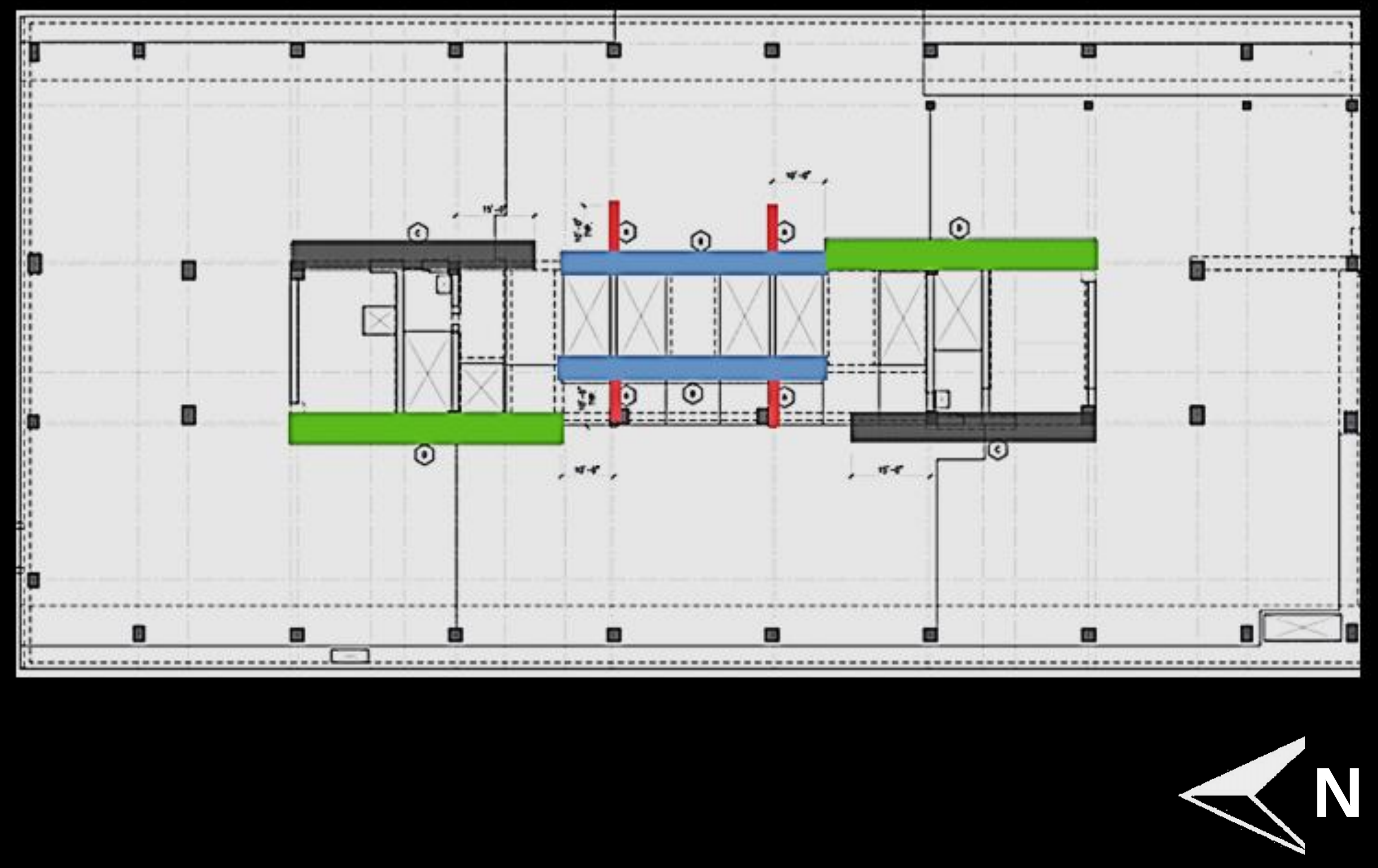
- Gravity System
  - Foundation
  - Floor System
- Lateral System
  - **Shear Walls**
    - Existing Torsional Irregularity
  - Collectors





Existing Structural Overview

- Gravity System
  - Foundation
  - Floor System
- Lateral System
  - Shear Walls
  - **Collectors**
    - N-S Direction at Lower Levels



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Design Scenario

- Redesign the building in steel
- Modify lateral system to eliminate existing torsional irregularity
- Determine Impact
  - Architecture
  - Serviceability – Walking induced vibrations
  - Cost and schedule

Proposed Solution

- Use original column locations
- Determine configuration of composite steel beams to control vibrations
- Add steel moment frames to building perimeter to control torsion
- Determine floor-to-ceiling height impact
- Compare costs and schedules

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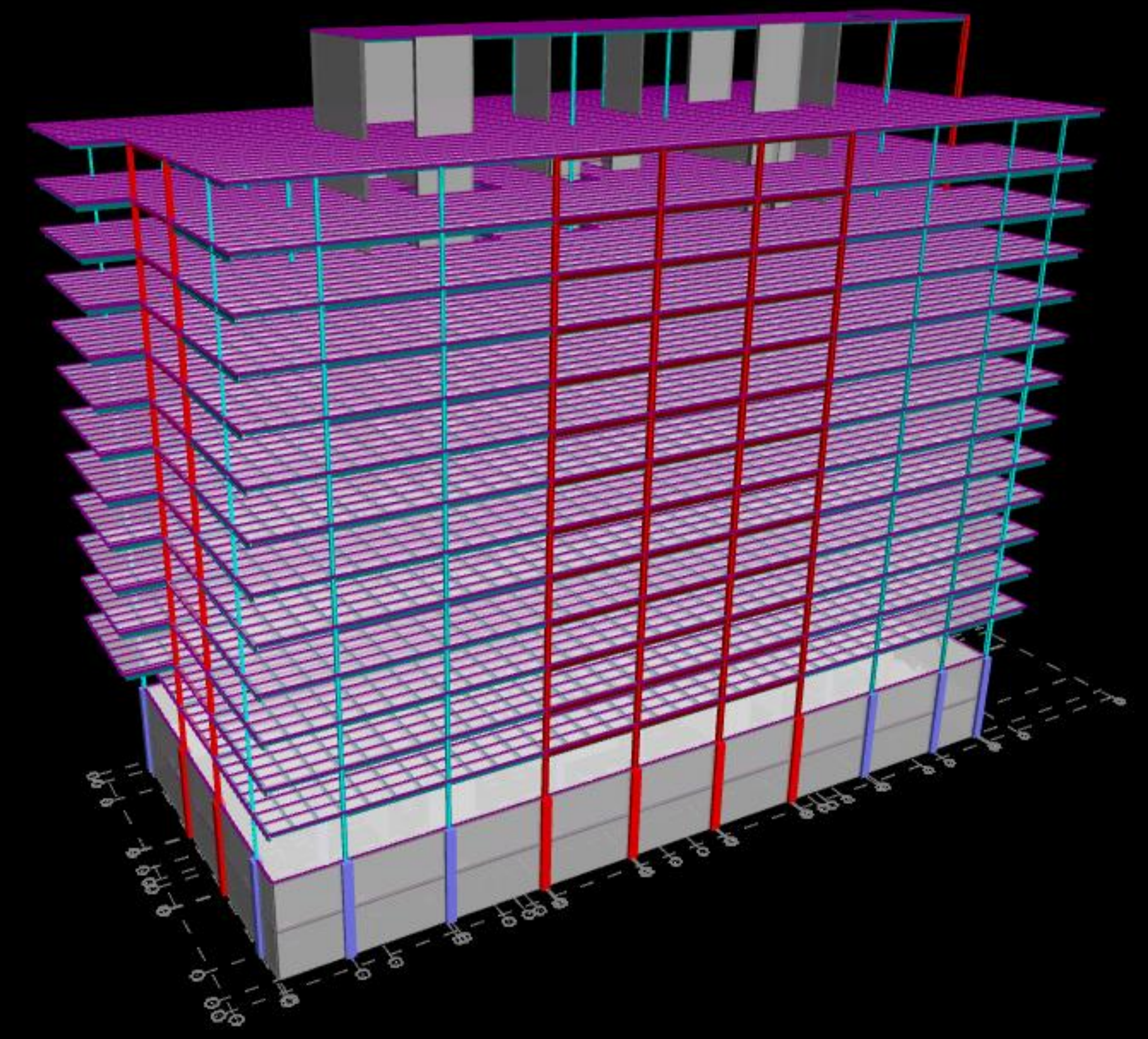
Gravity Redesign



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Preliminary Vibrations Analysis

- Vibrations due to human excitation
- Control peak acceleration of the bay

Design Selection:

- 1.5VLR20
- 4.25” LW Topping
- 7.5’ – 8’ beam spacing

Deck Configuration for Vibration Control	
Concrete Strength	3000 psi
Steel Grade	50
Deck Type	1.5VLR20
Topping (in)	4.25
LW/NW?	LW
Total Slab Thickness (in)	5.75
Class	4
Select C1	0.413
Select C2	0.019
Evaluate C1 + C2	0.432
C1 + C2 < 0.5?	GOOD

Source: *The Preliminary Assessment for Walking-Induced Vibrations in Office Environments* by Dr. Linda Hanagan and Taehoo Kim

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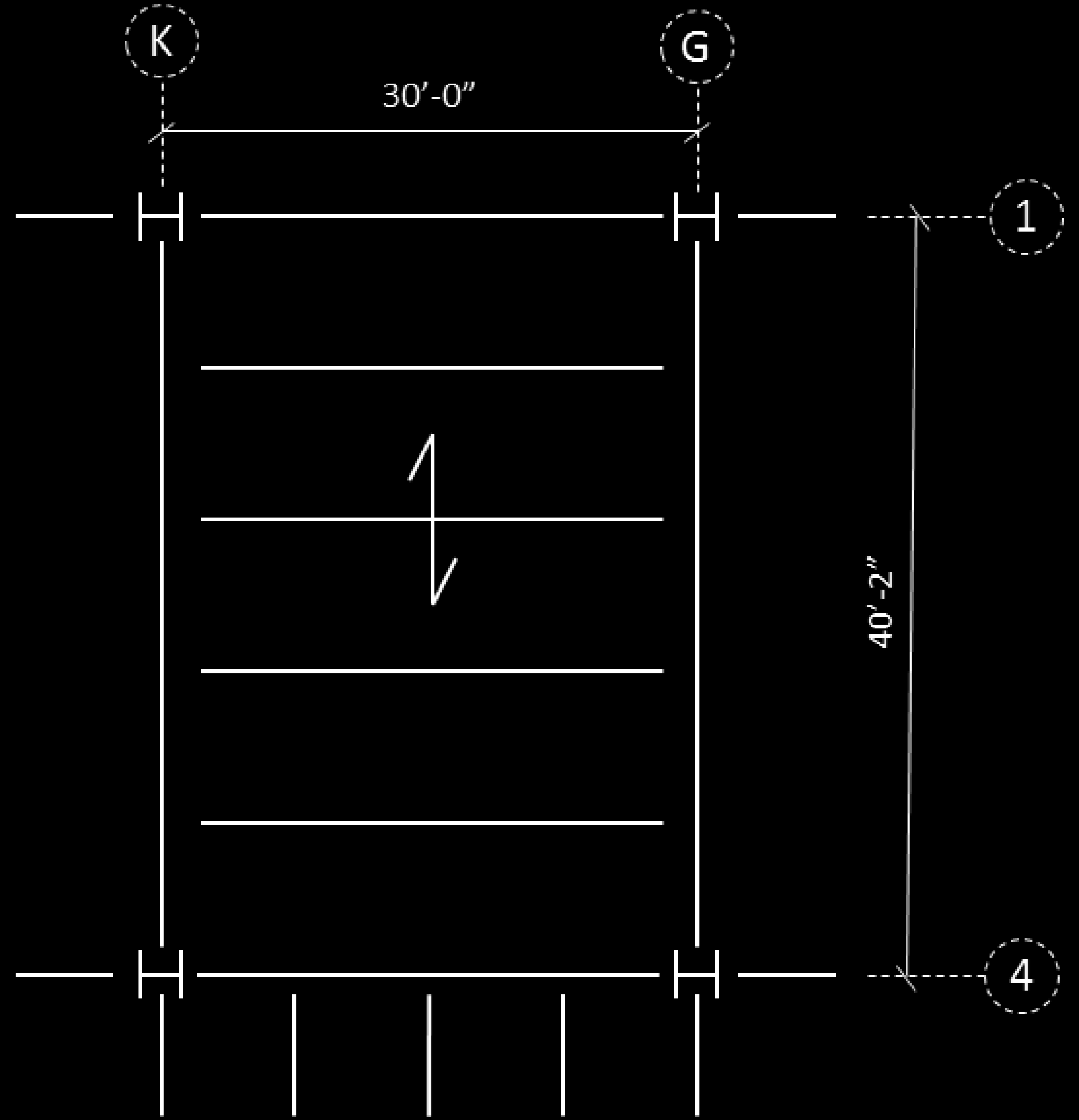
Gravity System Layout

- Which direction to span infill beams?
  - **Short**
  - Long
- Long Direction Selected



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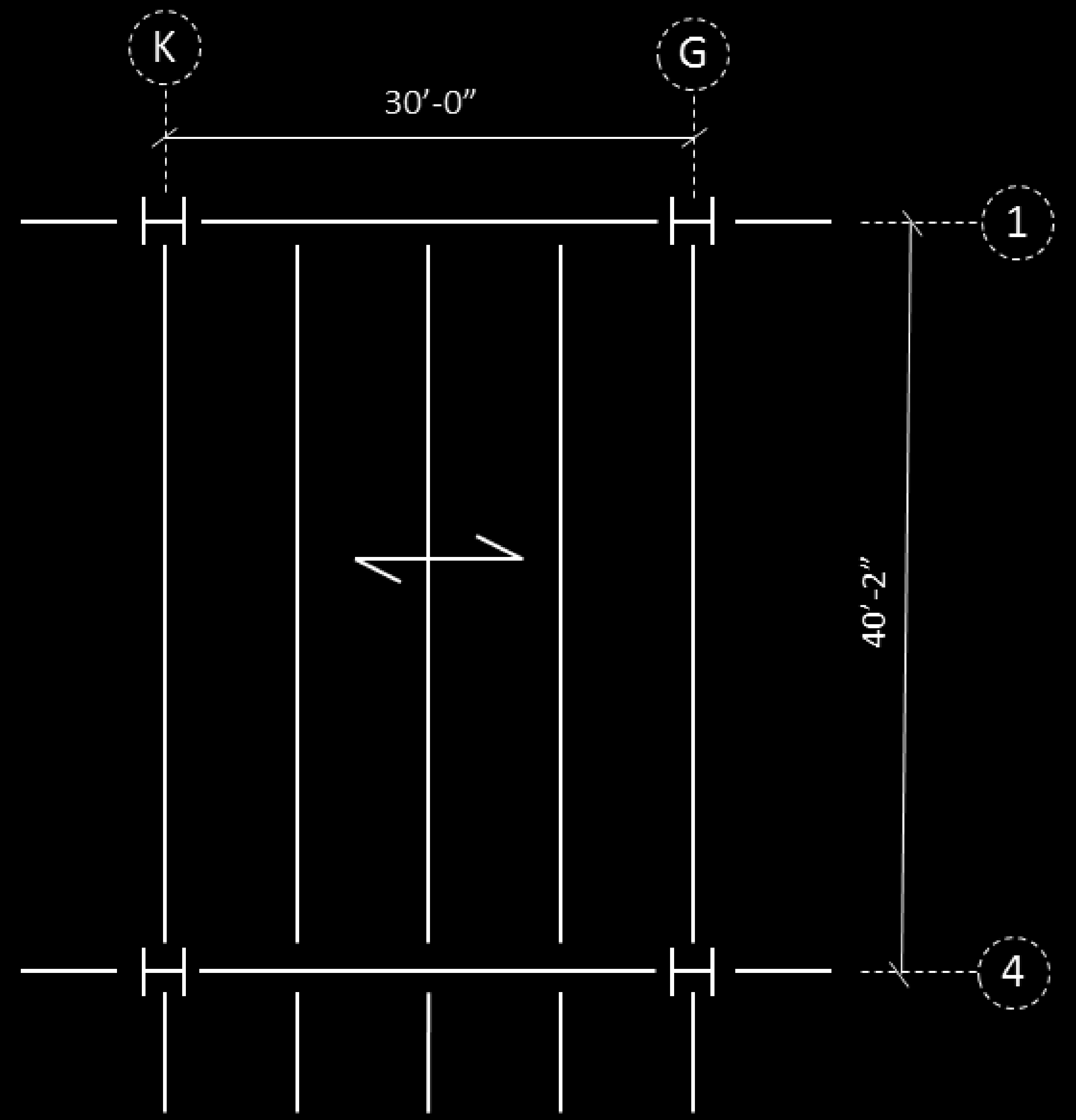
Gravity System Layout

- Which direction to span infill beams?
  - Short
  - **Long**
- Long Direction Selected



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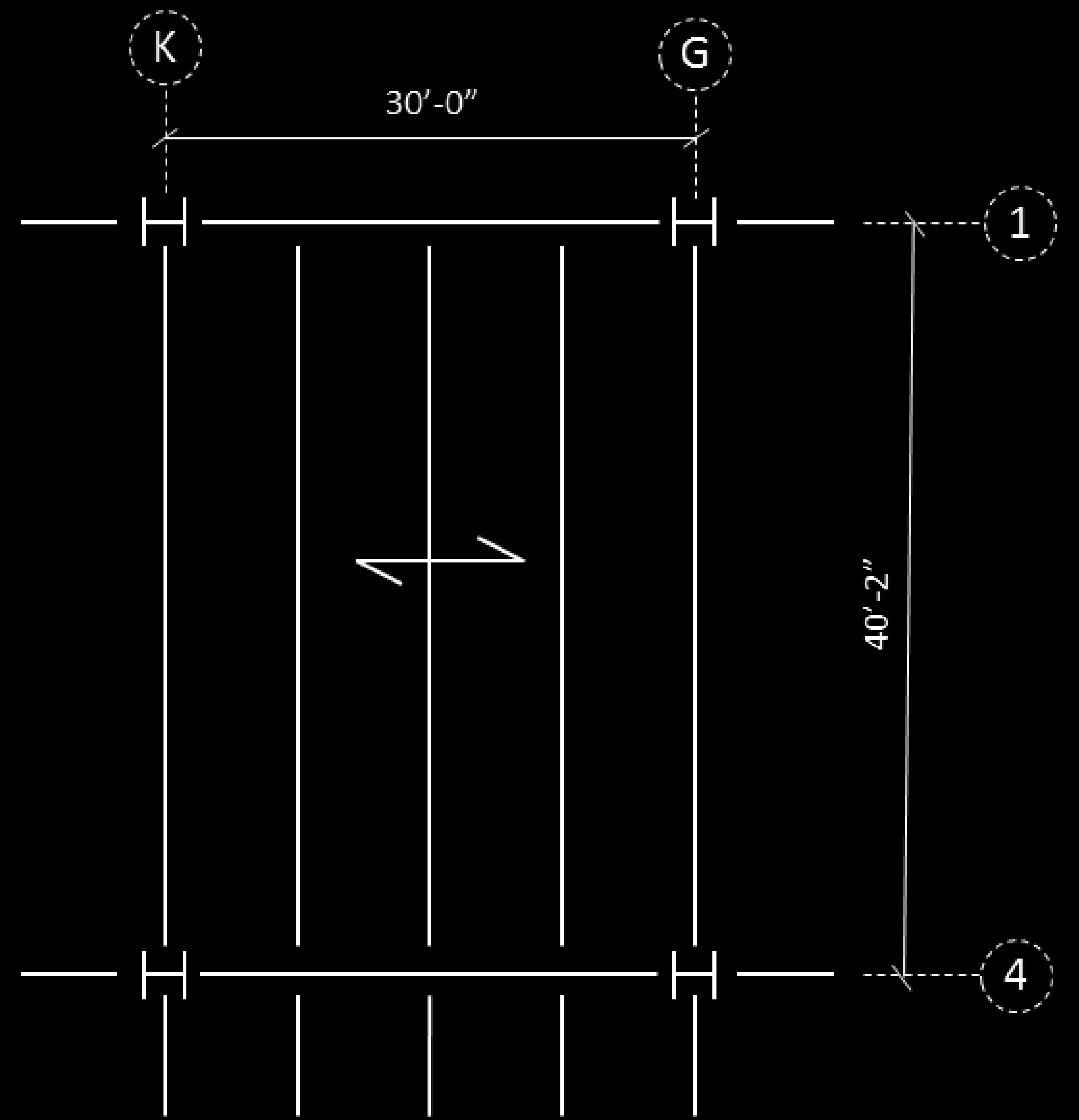
Gravity System Layout

- Which direction to span infill beams?
  - Short
  - Long
- **Long Direction Selected**

Infill Beam Comparison		
	Steel Weight (lbs)	Number of Members
Long Direction	212936	155
Short Direction	179608	225



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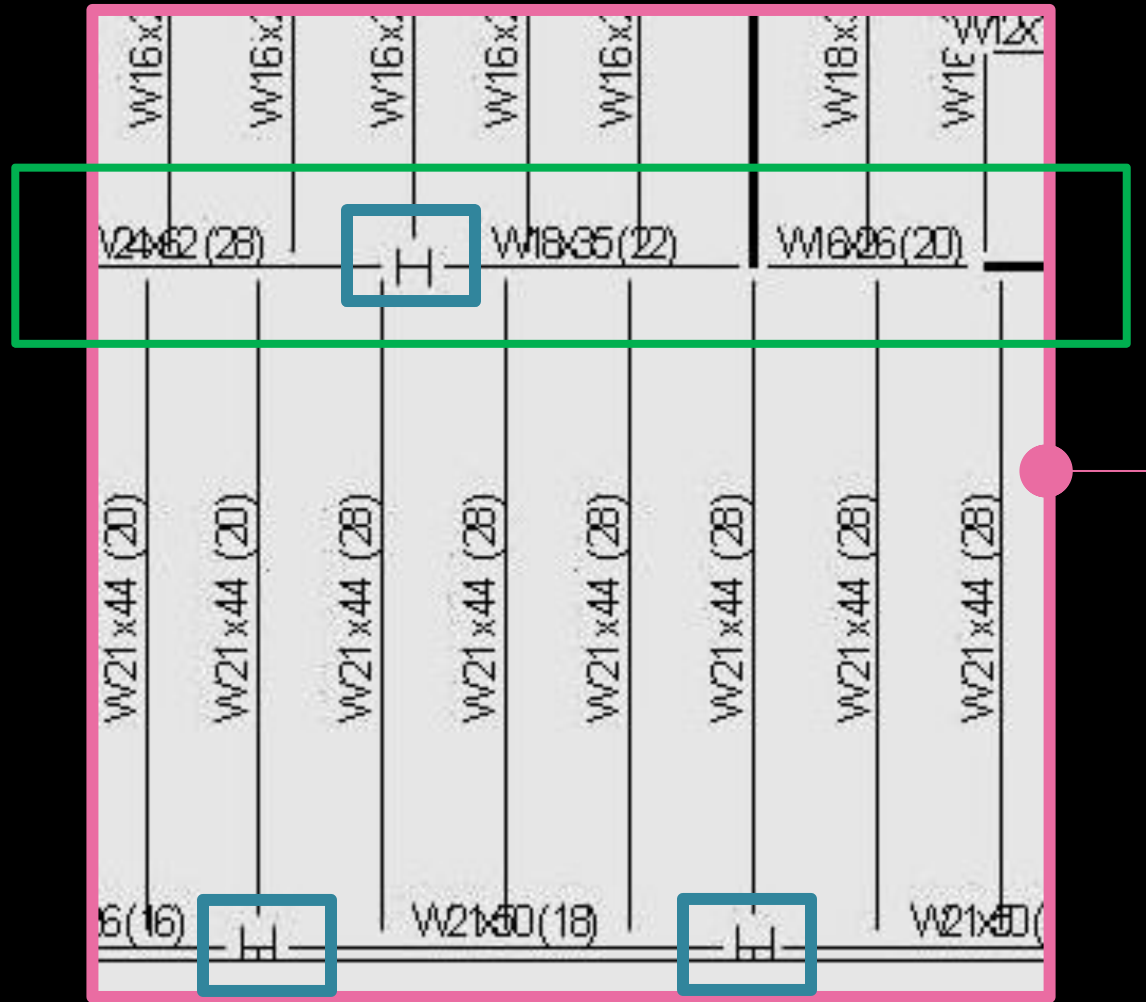
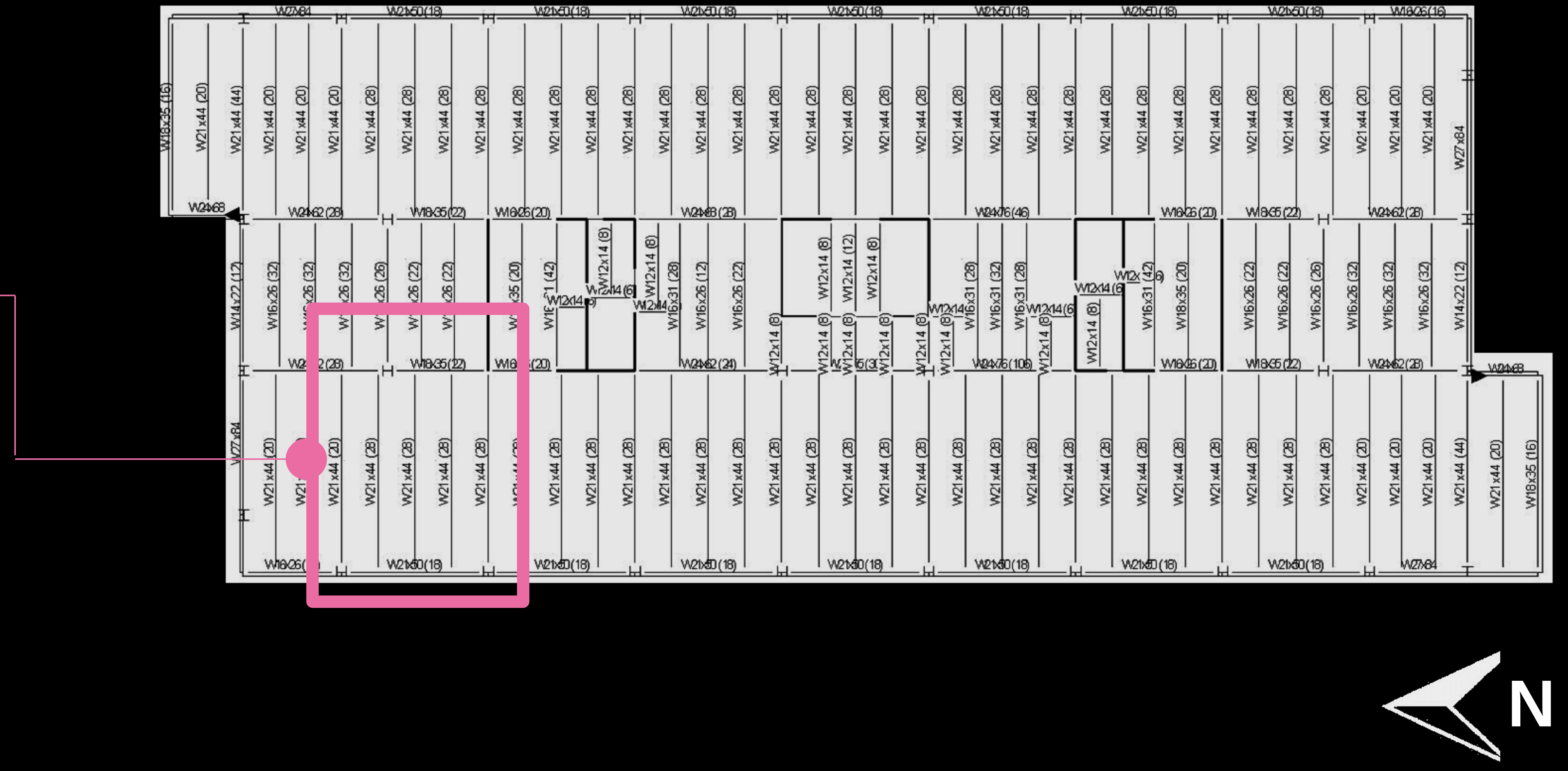
Gravity System Layout

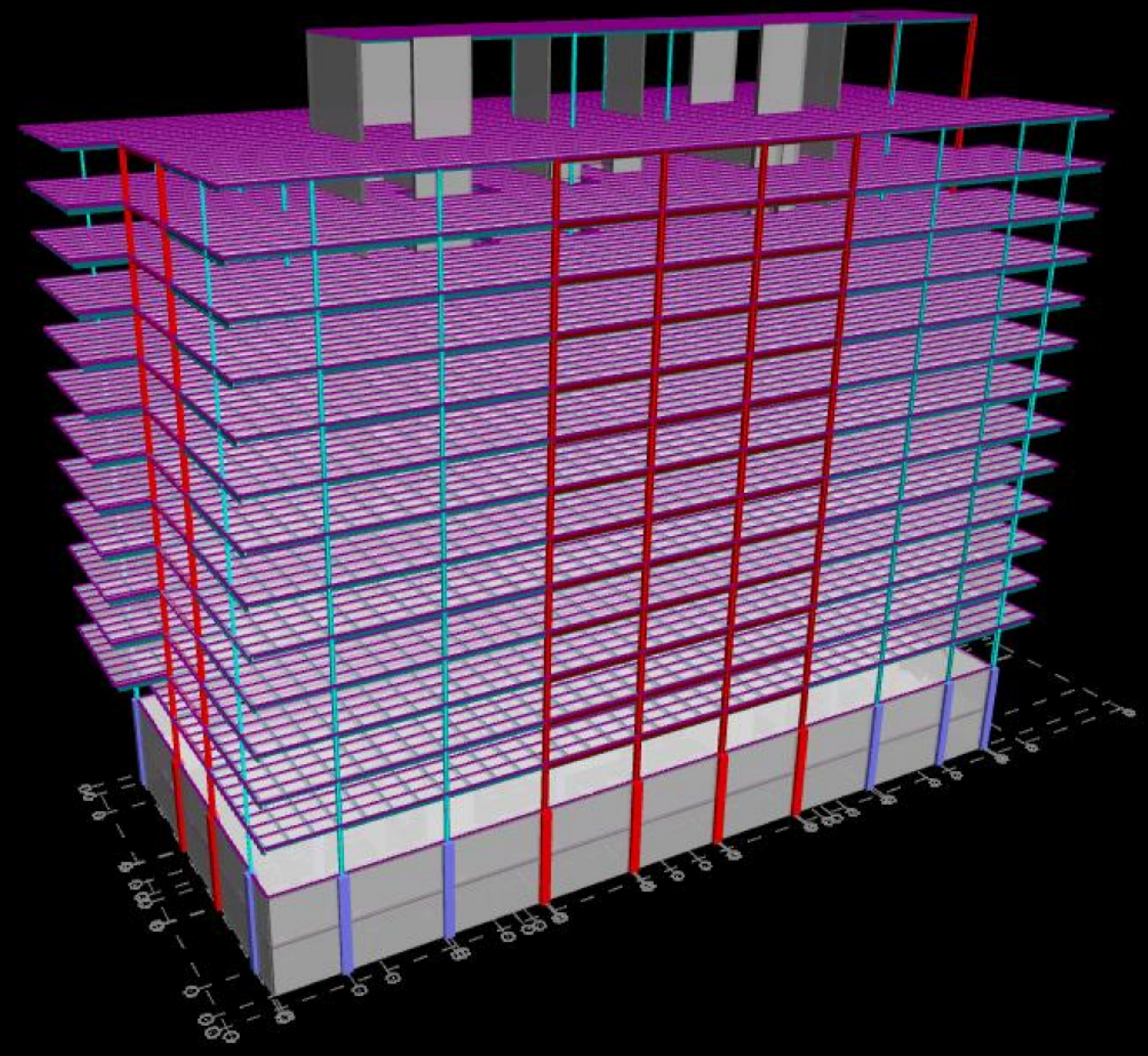




RAM Gravity Model

- RAM SS used to develop gravity designs
  - Composite steel beams
  - Steel columns
- Several designs verified by hand calculations

Gravity Loads		
	Dead (PSF)	Live (PSF)
Core	90	250
Lease Space	90	80



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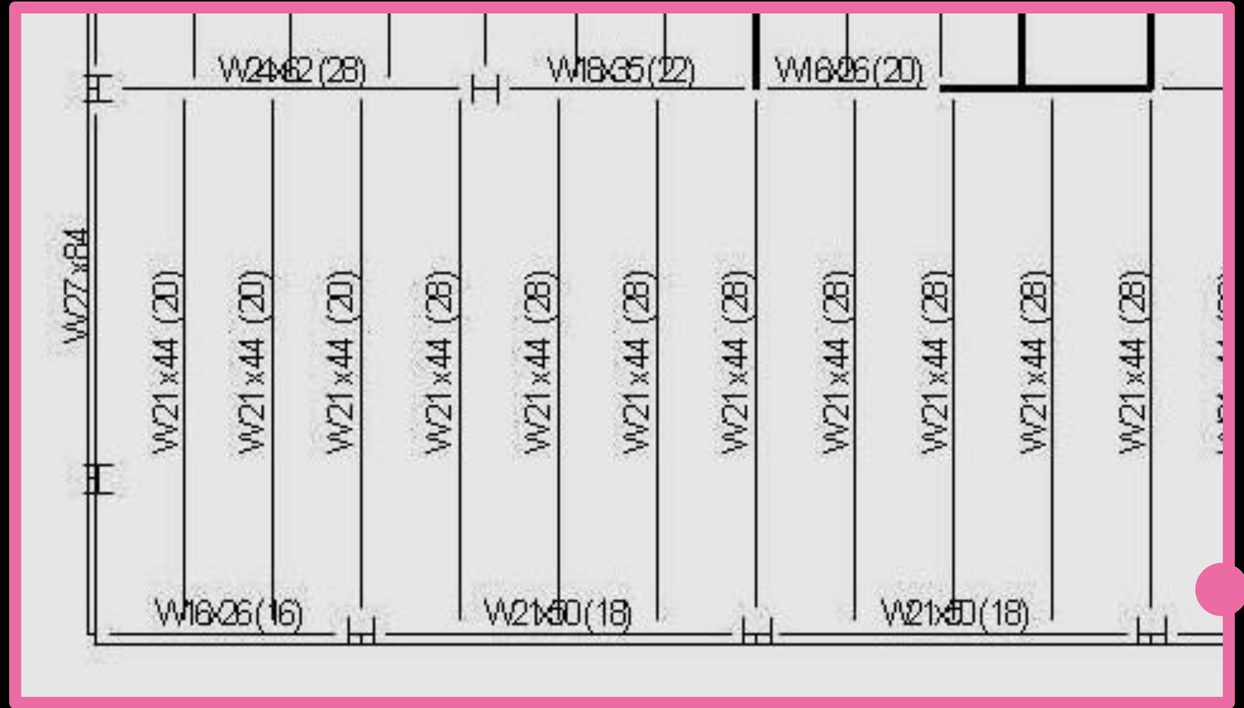
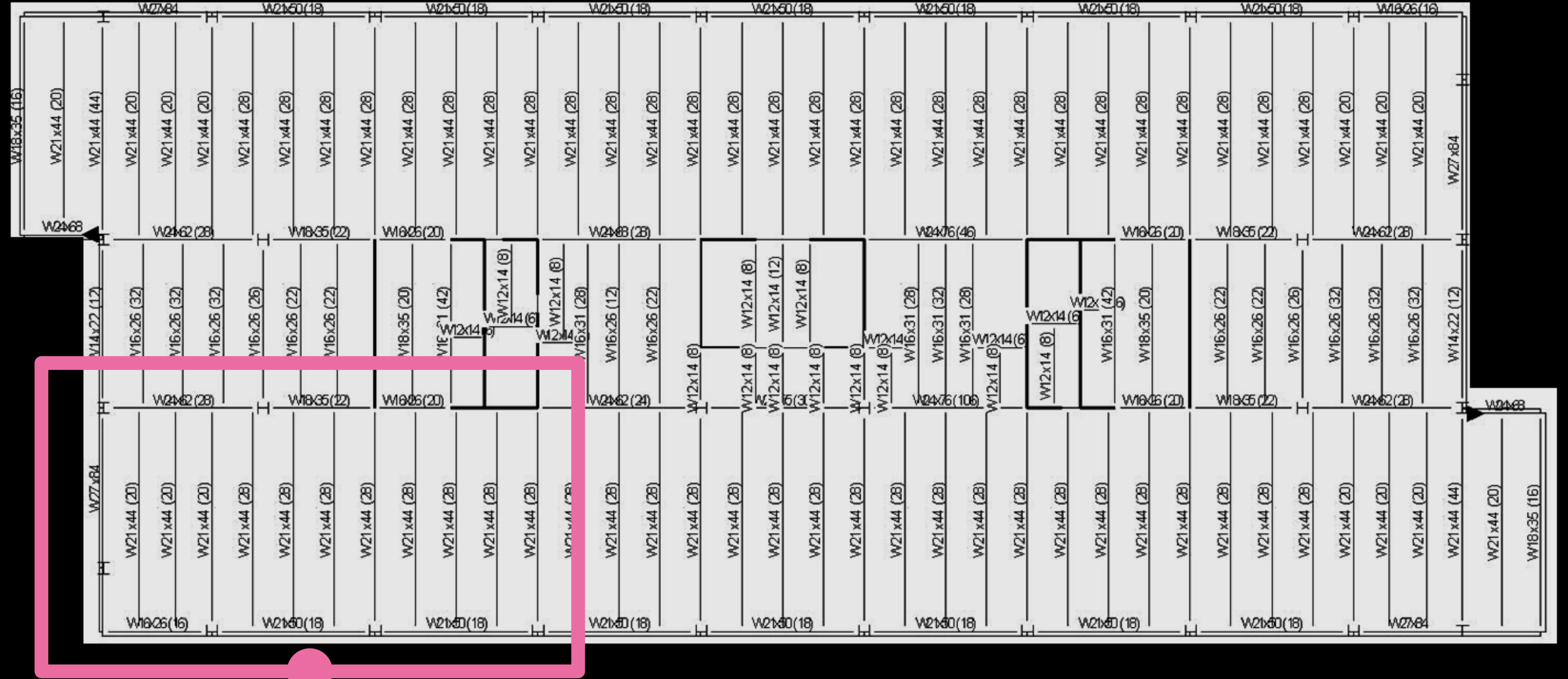
Beam Designs

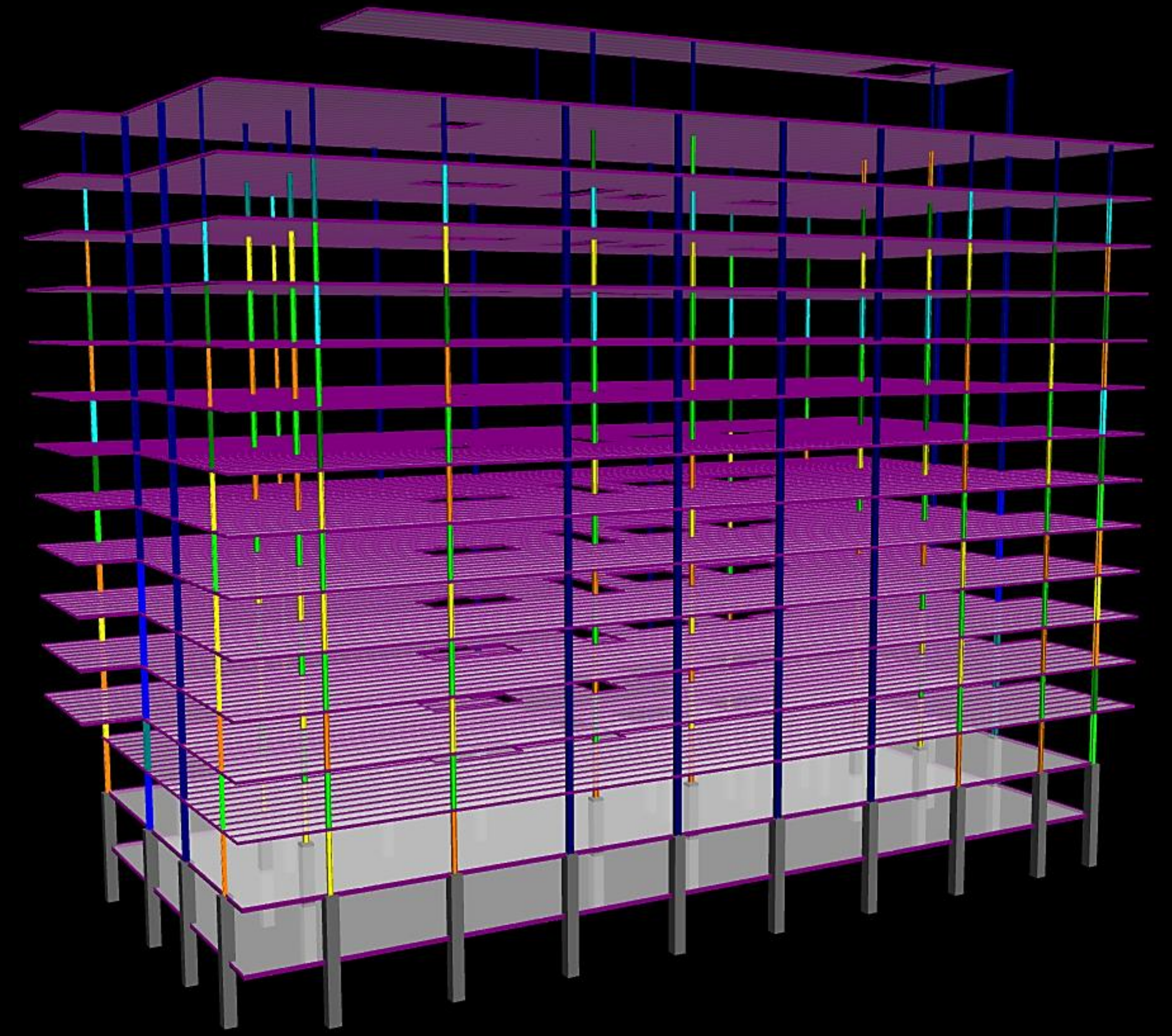
- Common Member Sizes:
  - W21x44 (28) infill exterior bays
  - W24x62 (32) infill interior bays
  - W21x50 (18) exterior girder





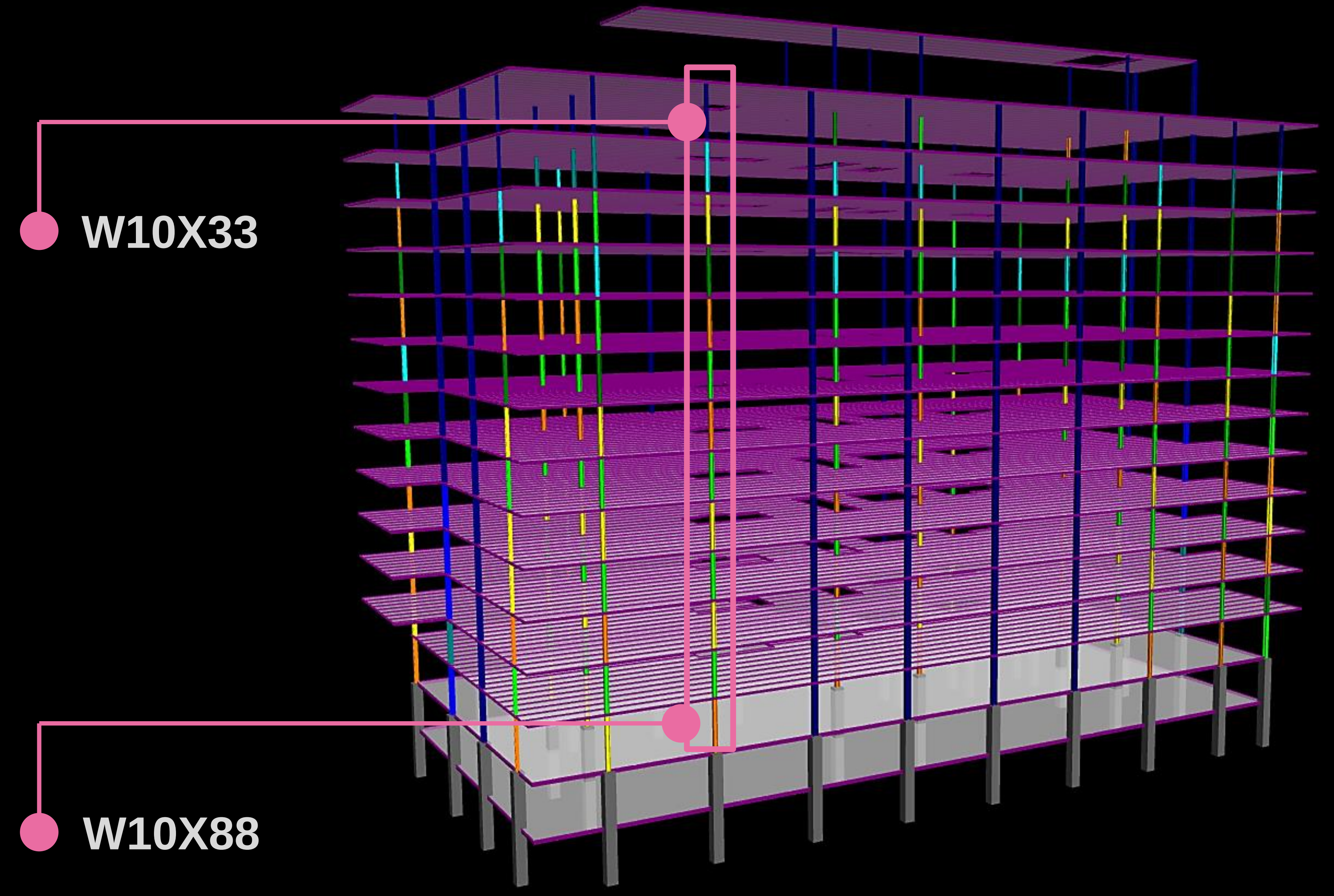
Column Designs

- Spliced every 2 stories
- Each column line has consistent column depth



Column Designs

- Spliced every 2 stories
- Each column line has consistent column depth
  - **Exterior Column Line**



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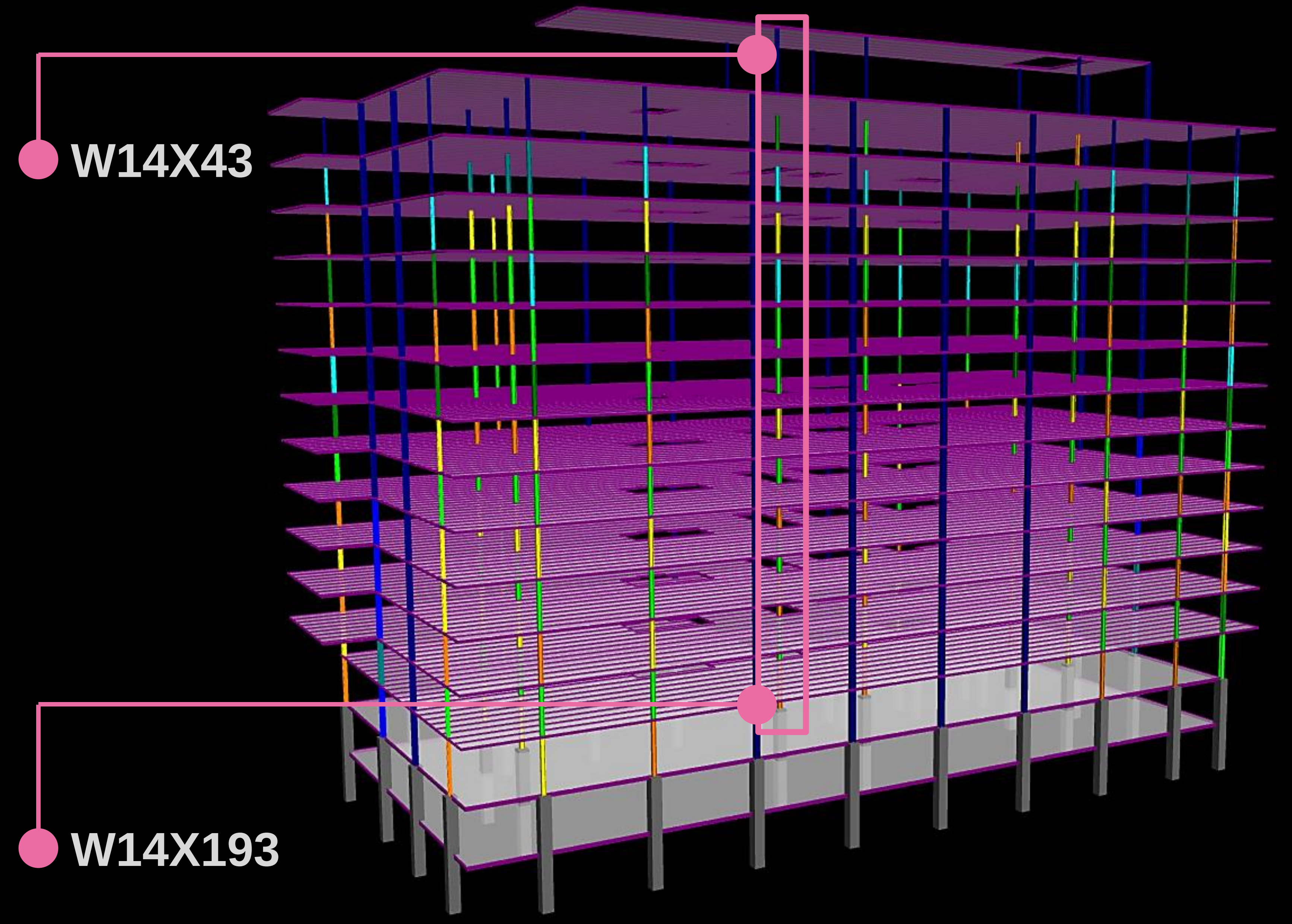
Column Designs

- Spliced every 2 stories
- Each column line has consistent column depth
  - Exterior Column Line
  - **Interior Column Line**



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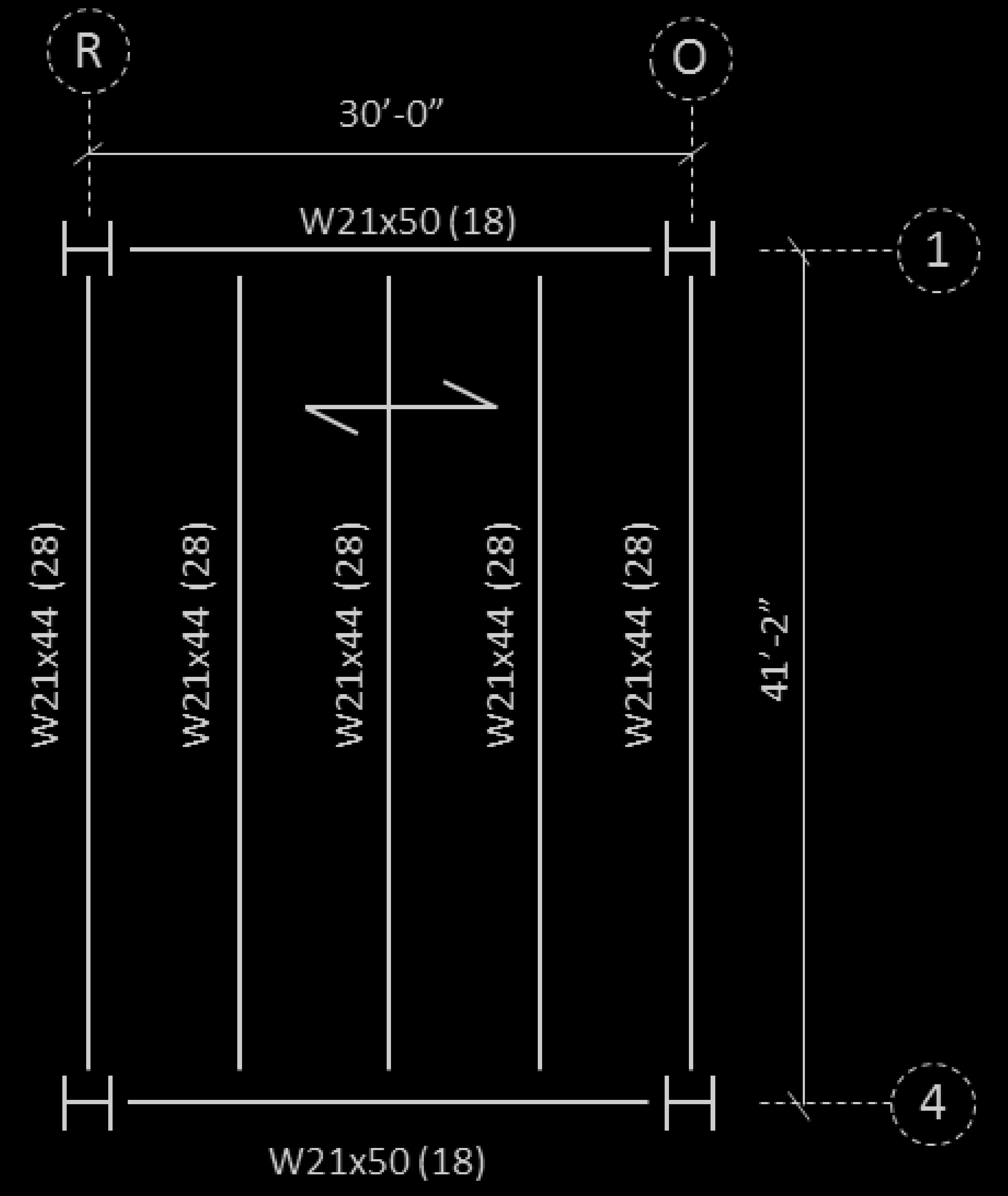
Final Vibrations Analysis

- AISC *Design Guide 11* analysis on a typical bay for walking induced vibrations
- Determine combined panel weight and natural frequency to determine bay peak acceleration
  - P_0 = 65 lb
  - β = 0.03
  - $a_0/g < 0.5\%$

From AISC DG 11 – Table 4.1

$$\frac{a_0}{g} \geq \frac{a_p}{g} \rightarrow 0.5\% \geq 0.38\%$$



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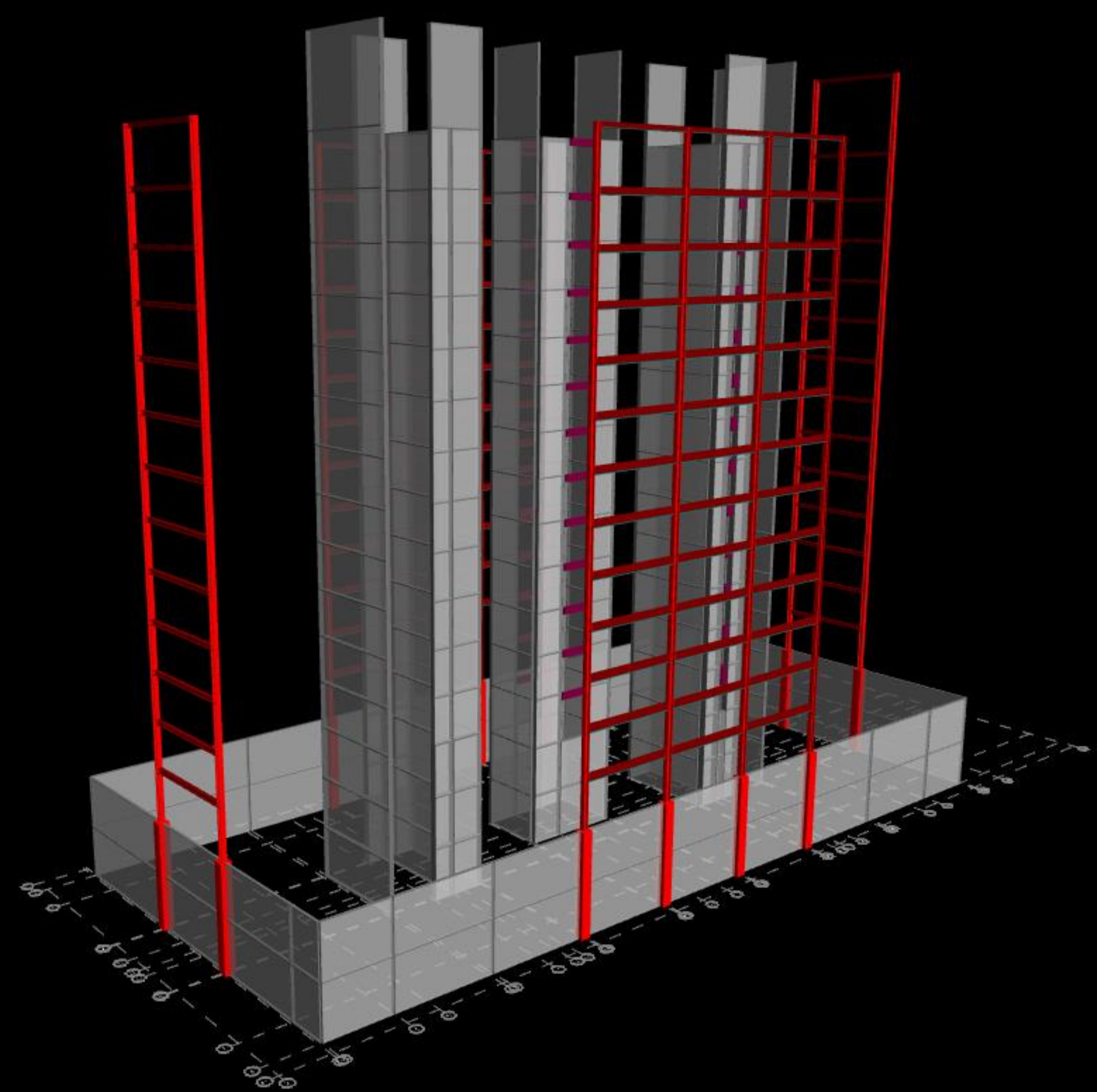
Lateral Redesign



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Lateral System

- Reduced building weight
  → Seismic loads decreased

- Building height unchanged
  → Wind loads unchanged

- **Seismic controls**

Base Shear (Kip)				
	Wind N-S	Wind E-W	Seismic N-S	Seismic E-W
Concrete	583	1615	7698	7698
Steel	583	1615	4935	4408

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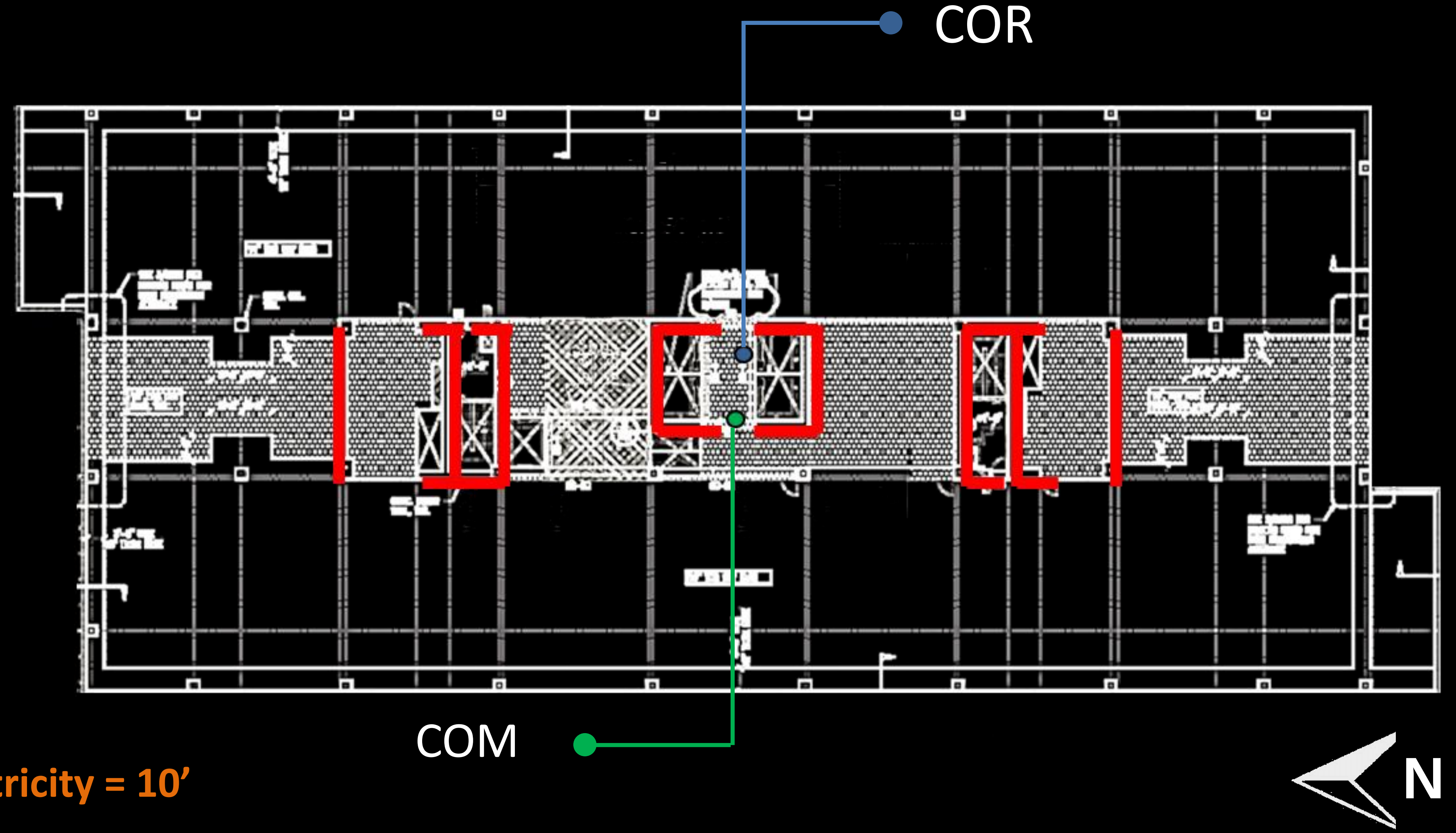
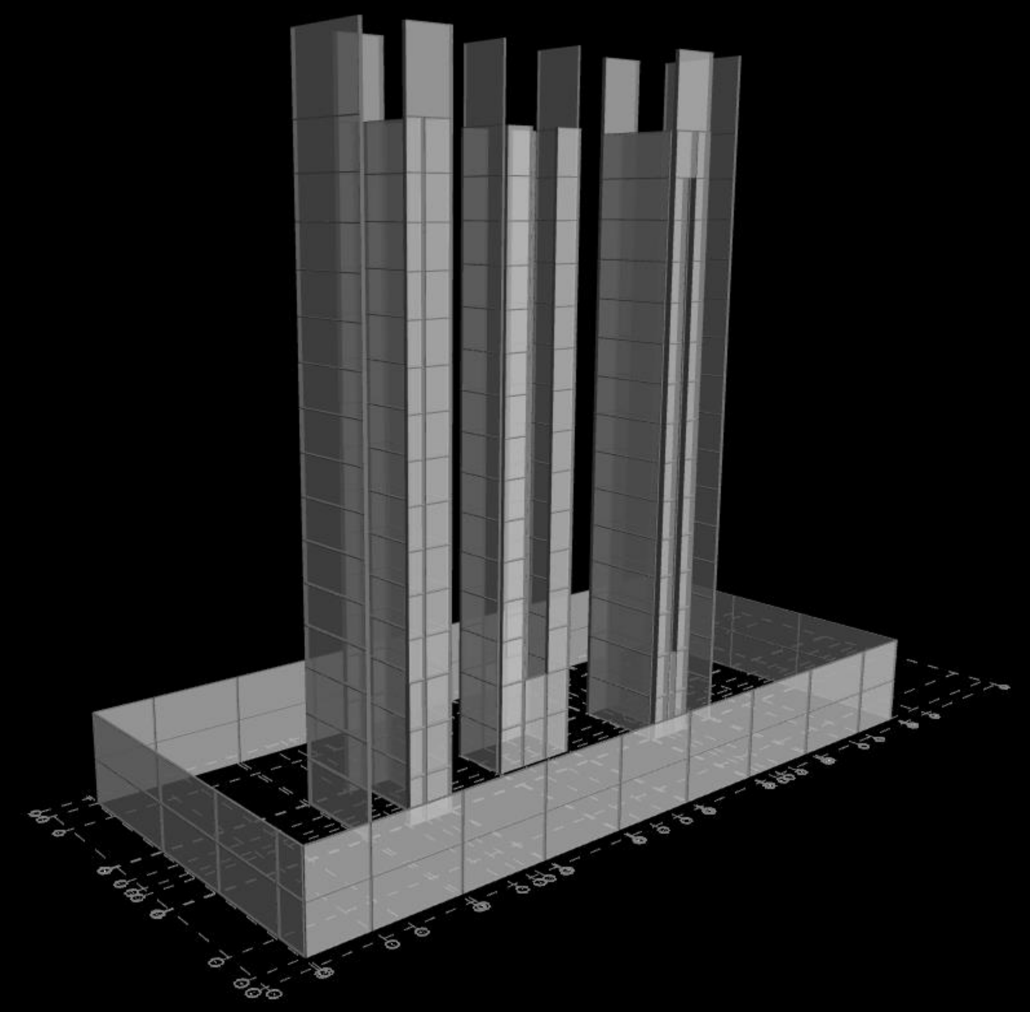
Existing Lateral System Layout



Eccentricity = 10’



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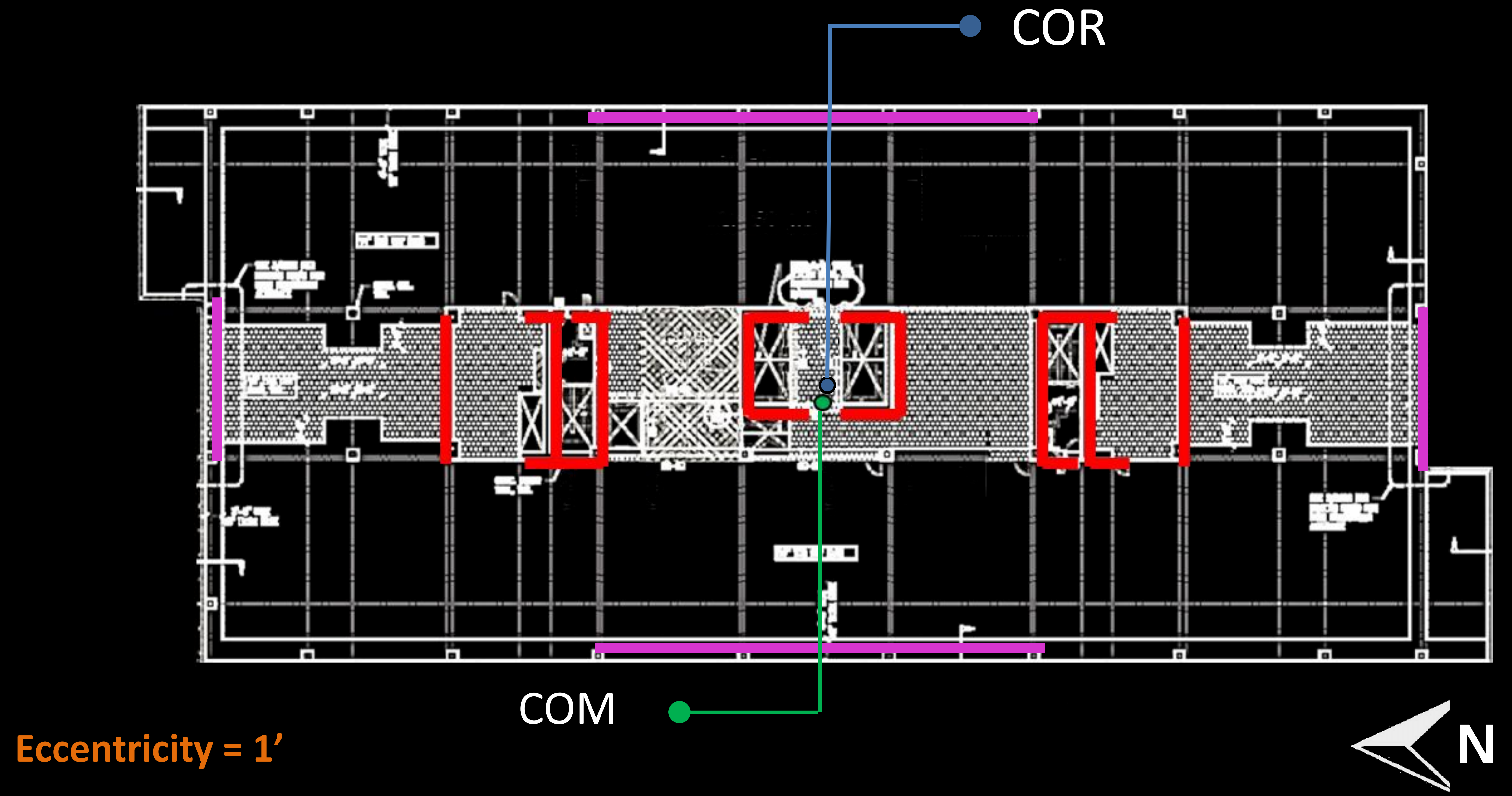
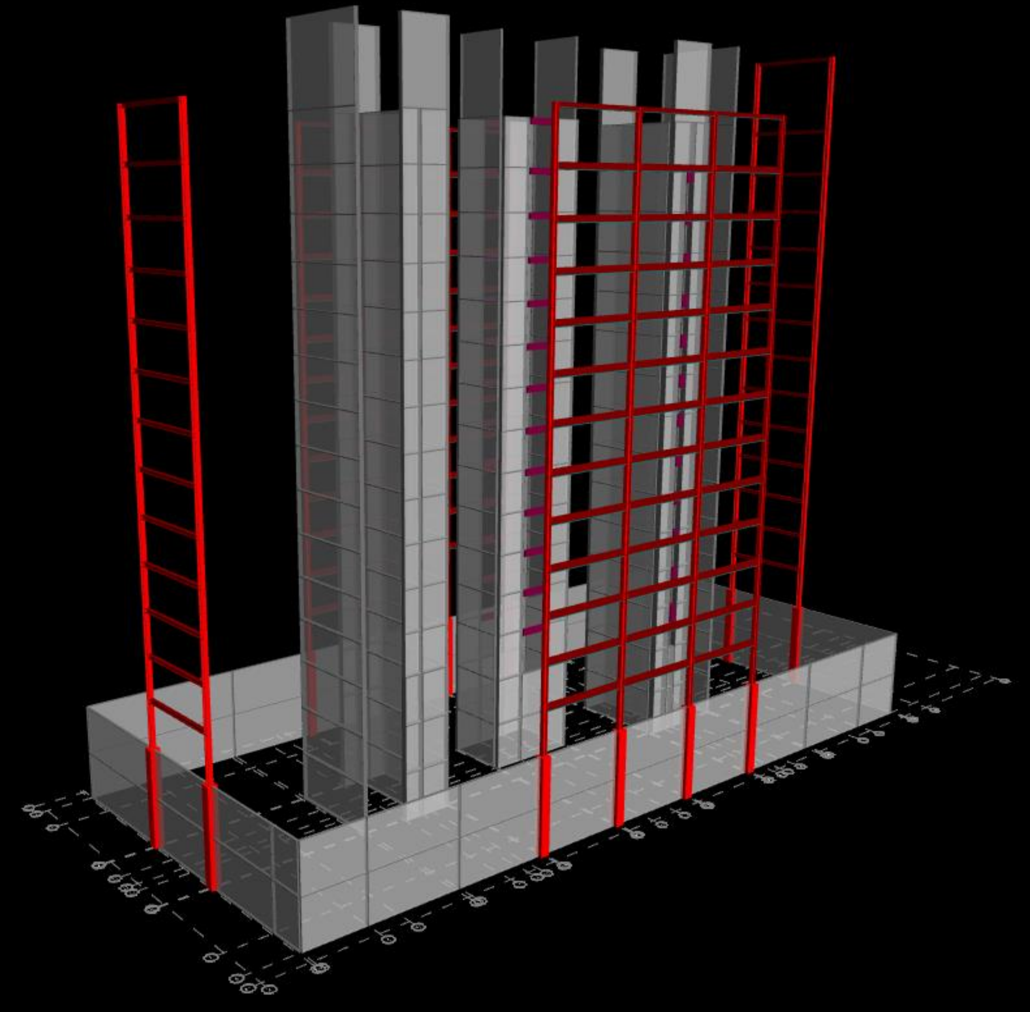
New Lateral System Layout





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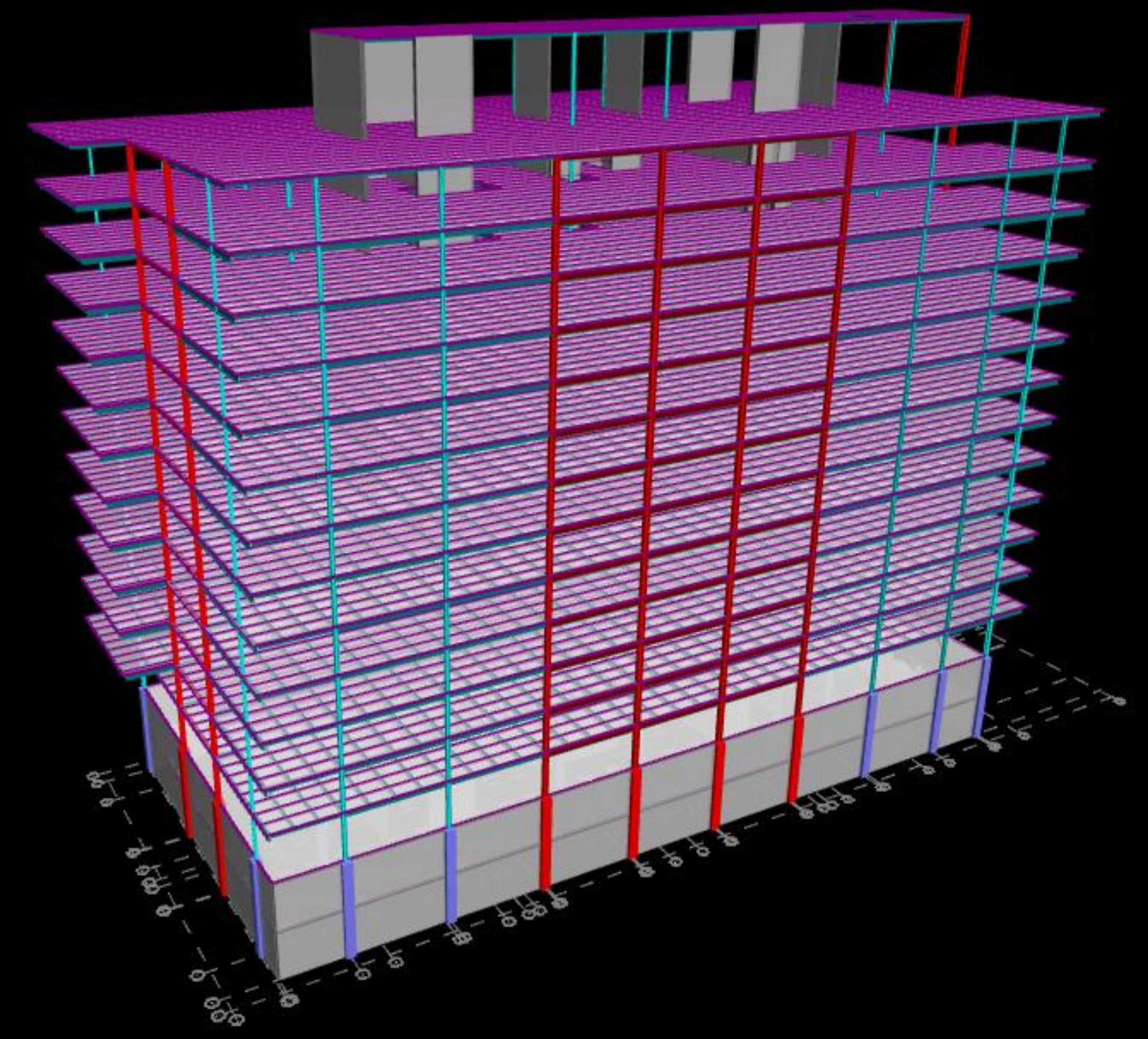
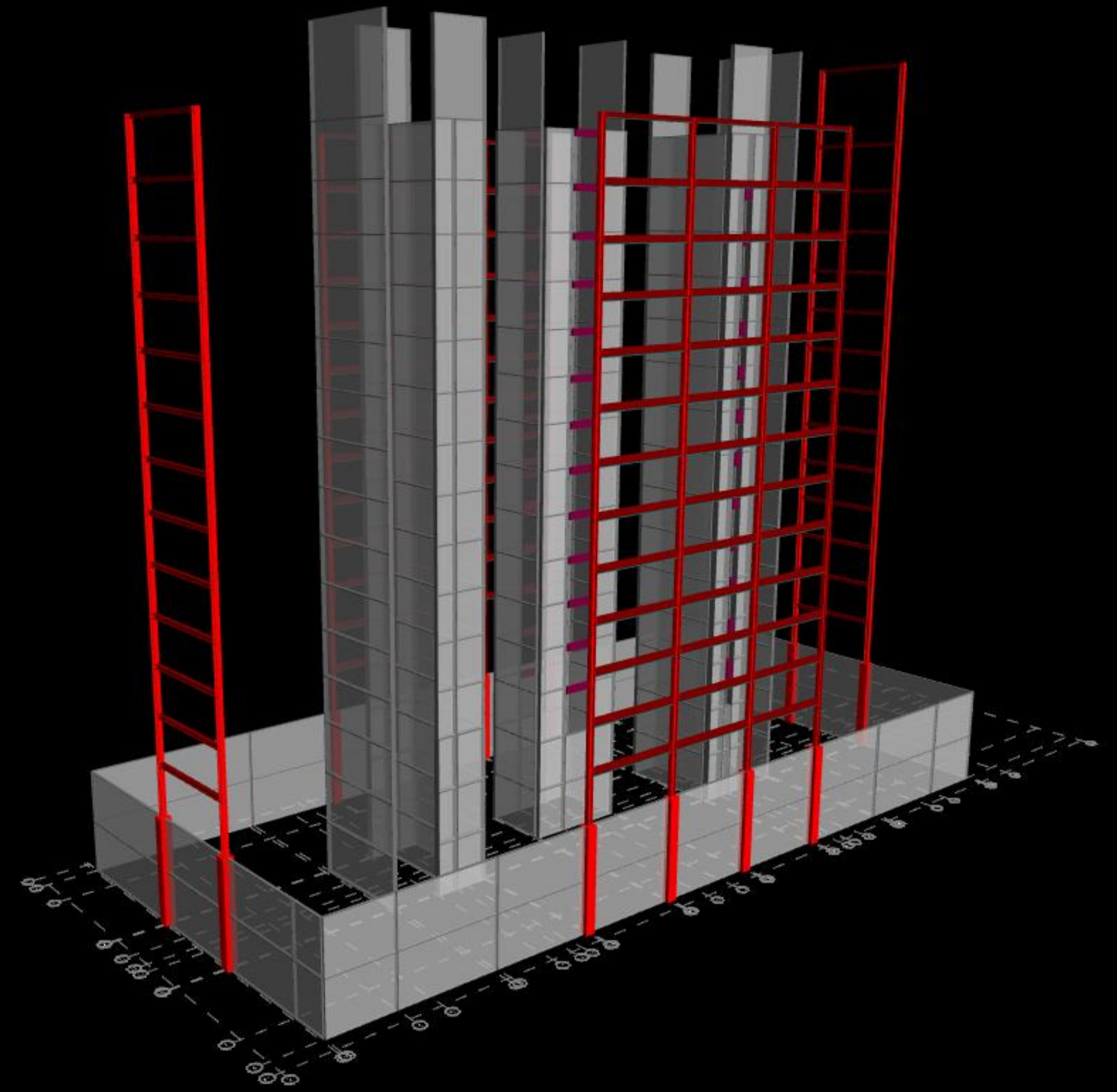
RAM Model

- Rigid diaphragms
- Wall shell elements neglect out of plane stiffness
- Stiffness reduction based on ACI 318-11
- Panel zone deformations considered
- Base constraints



Special Moment Frames

- Special moment frames required by ASCE 7-10
  - SDC D
  - 198’ > 65’
- Designed to be “clean column”
  - Strong panel zone
- Strength and joint optimizations for seismic



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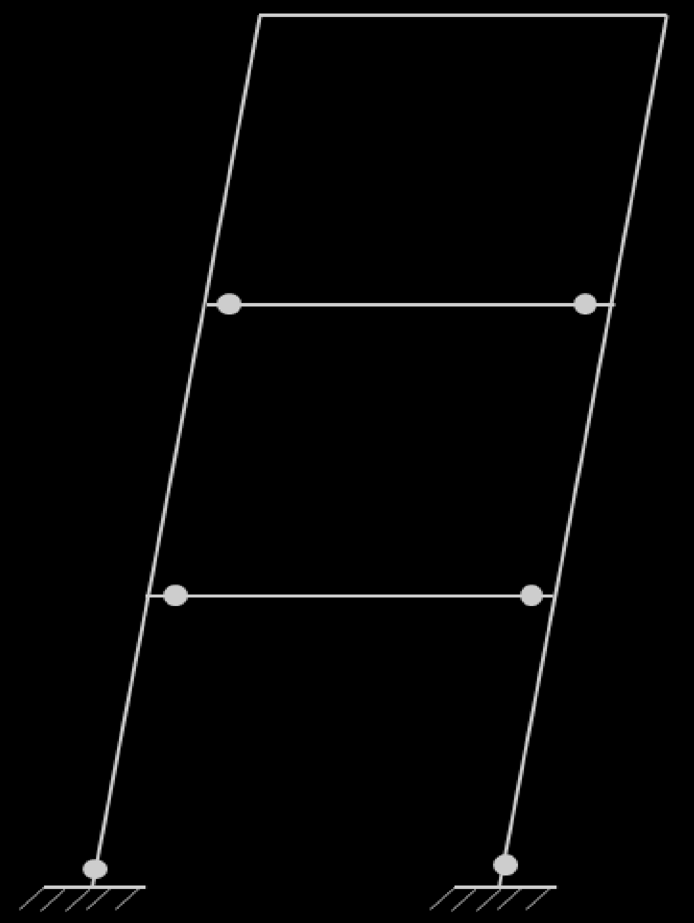
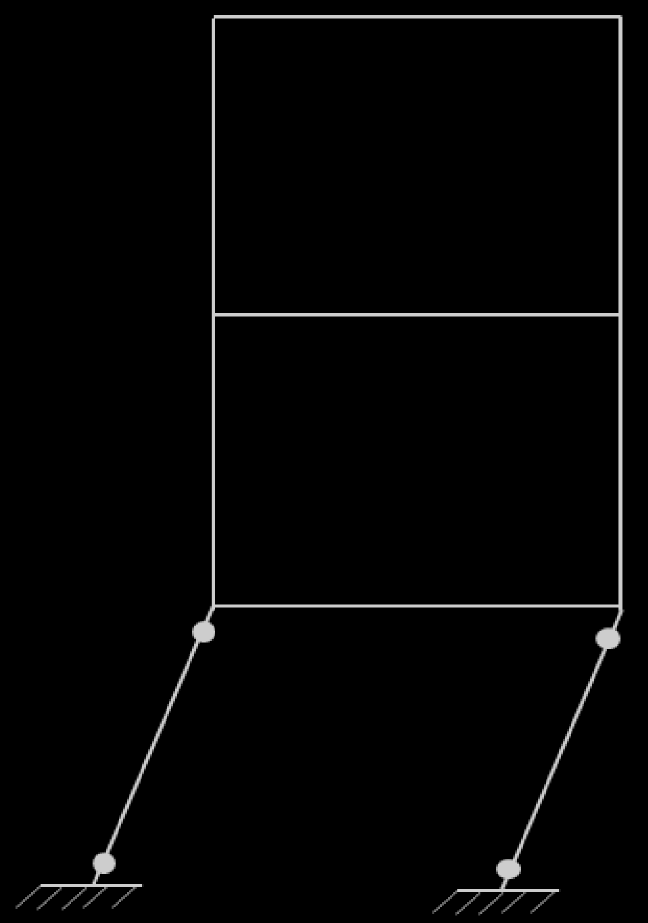
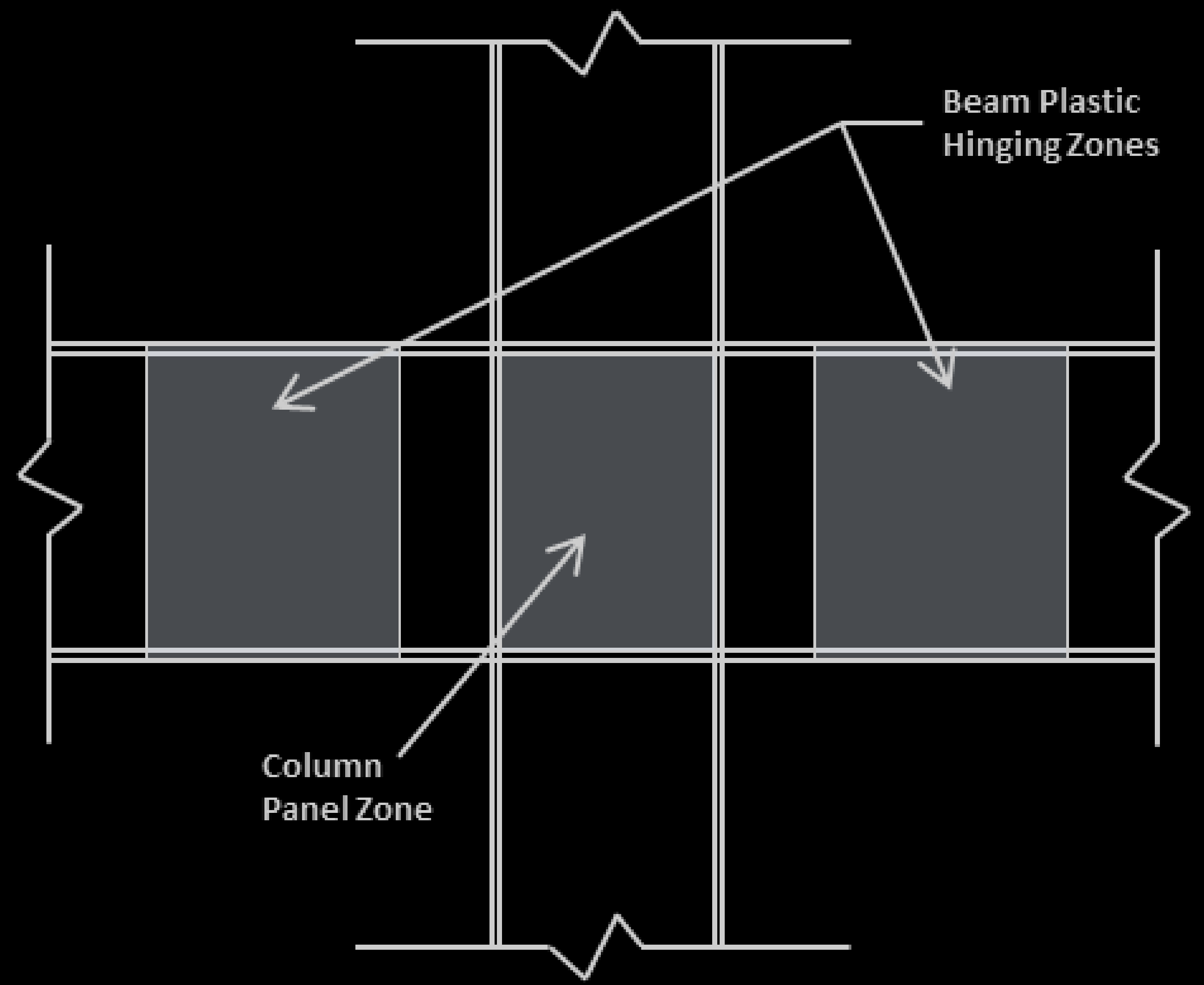
$$\frac{\sum M^*_{pc}}{\sum M^*_{pb}} > 1.0\ (Provisions\ Eq. E3)$$



Strong Column Weak Beam



Story Mechanism



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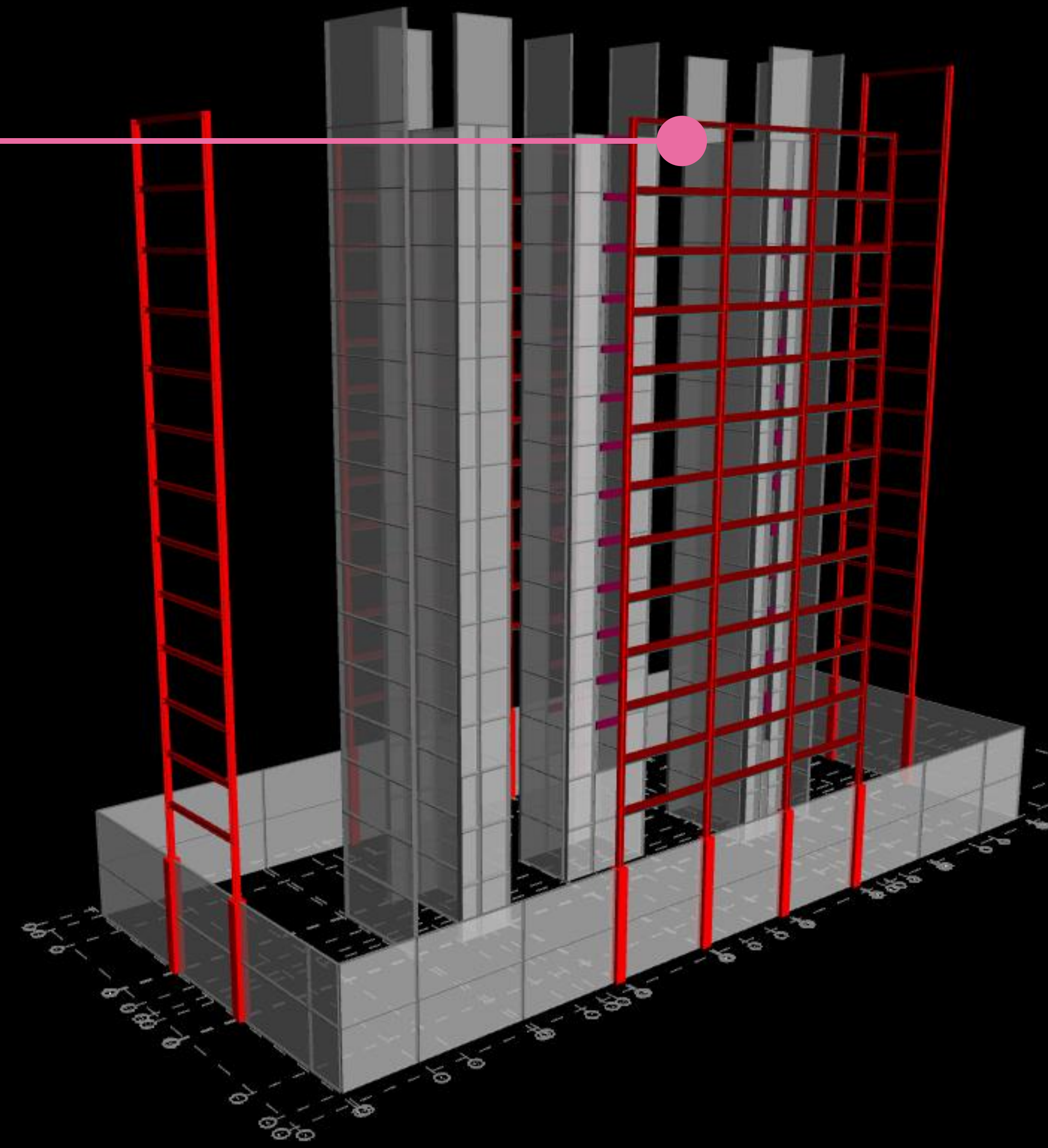
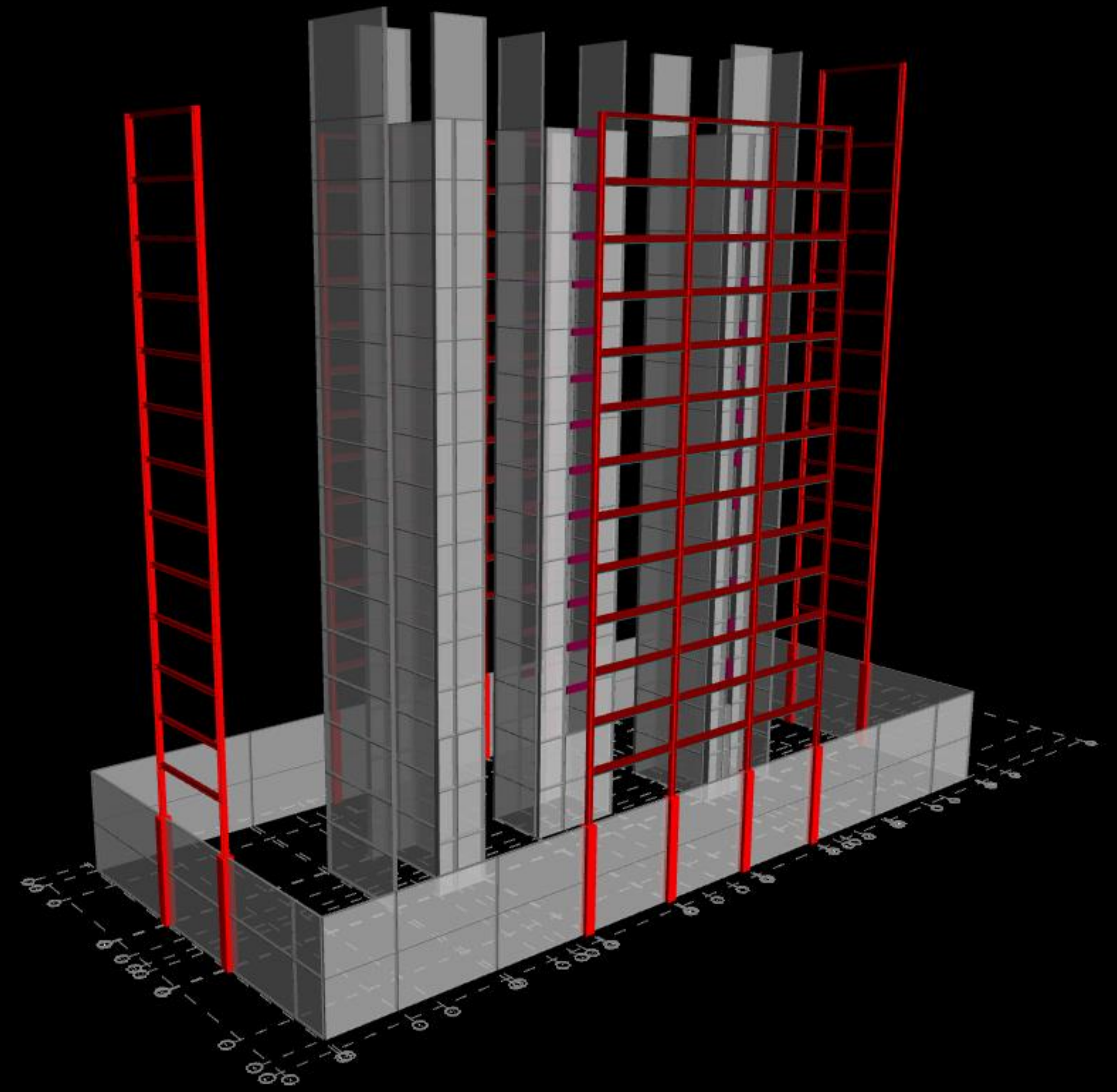
Levels 3-5

FRAME 1



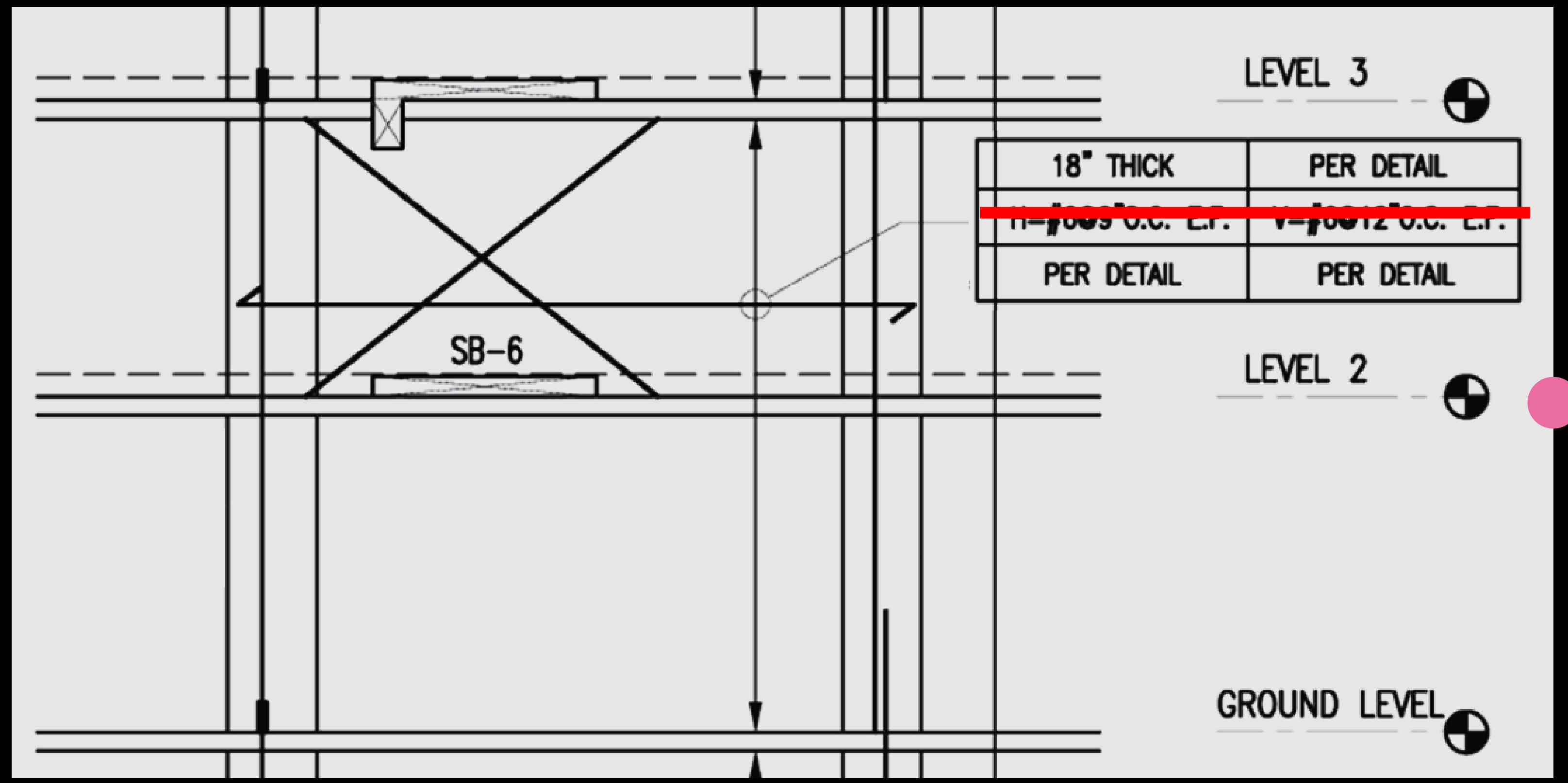
Special Concrete Shear Walls

- Thickness not reduced to control drift
- Reinforcing redesigned for reduced loads
  - According to ACI 318-11 Ch. 21

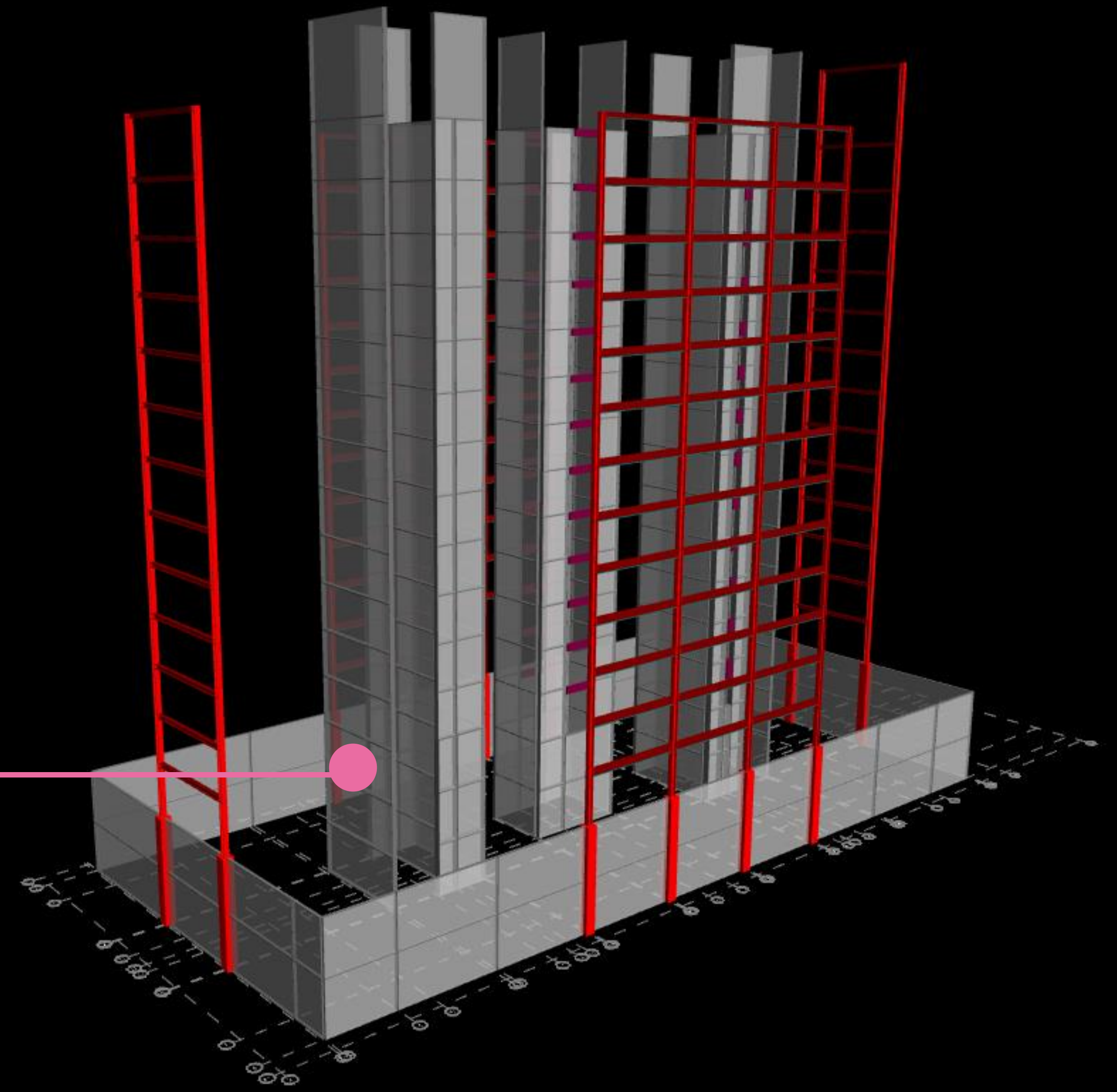


Special Concrete Shear Walls

- Shear Wall U Level 2– Reinforcing redesign
  - 7000 PSI NW Concrete, 18” Thick



H = #6 @ 9” O.C.
V = #6 @ 9” O.C.
One curtain only



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Architecture Breadth

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Floor-to-Ceiling Height

- Building height limited to 198'-8" by FAA
- Steel creates a deeper structural system than concrete
- Loss of floor-to-ceiling space

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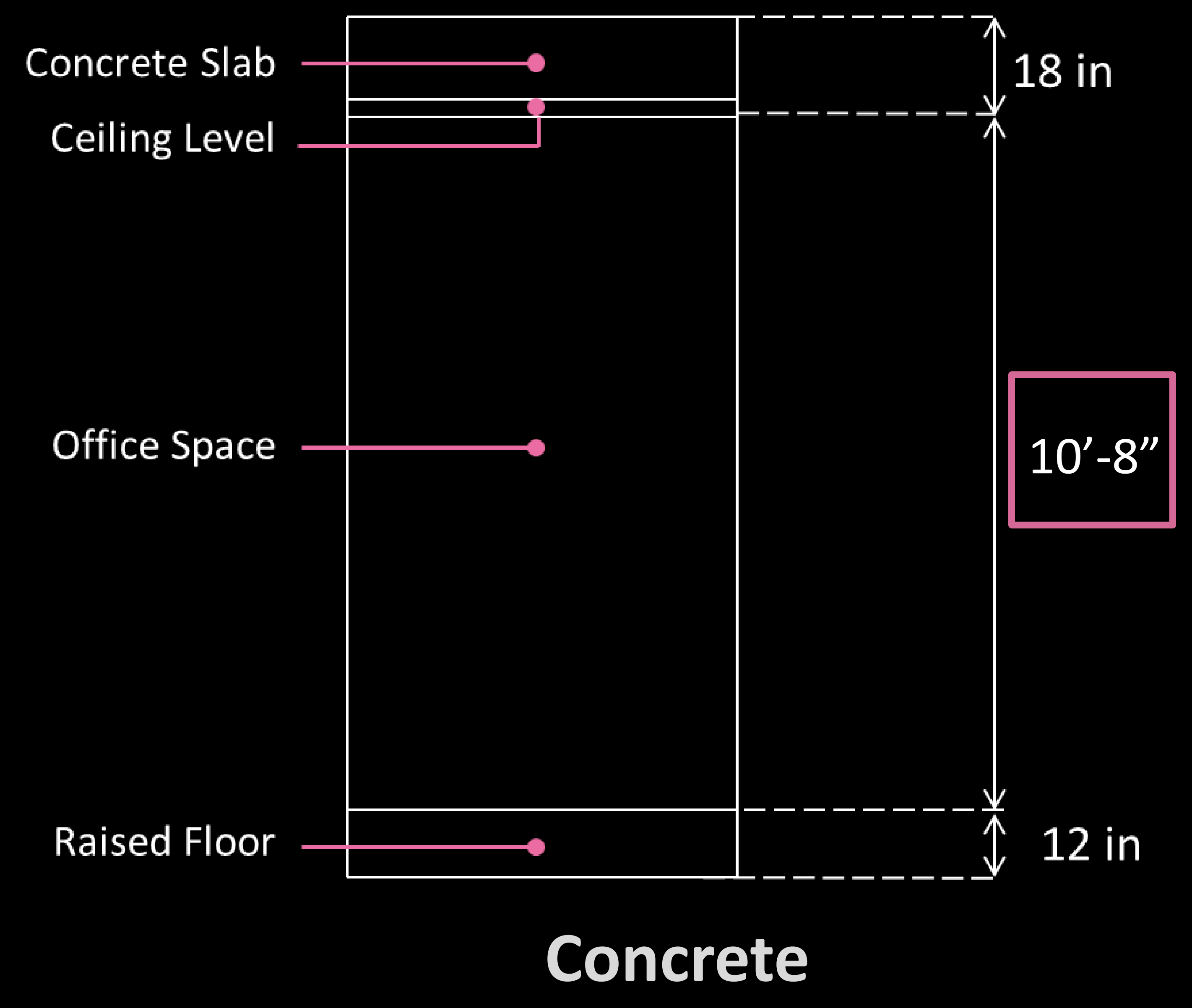
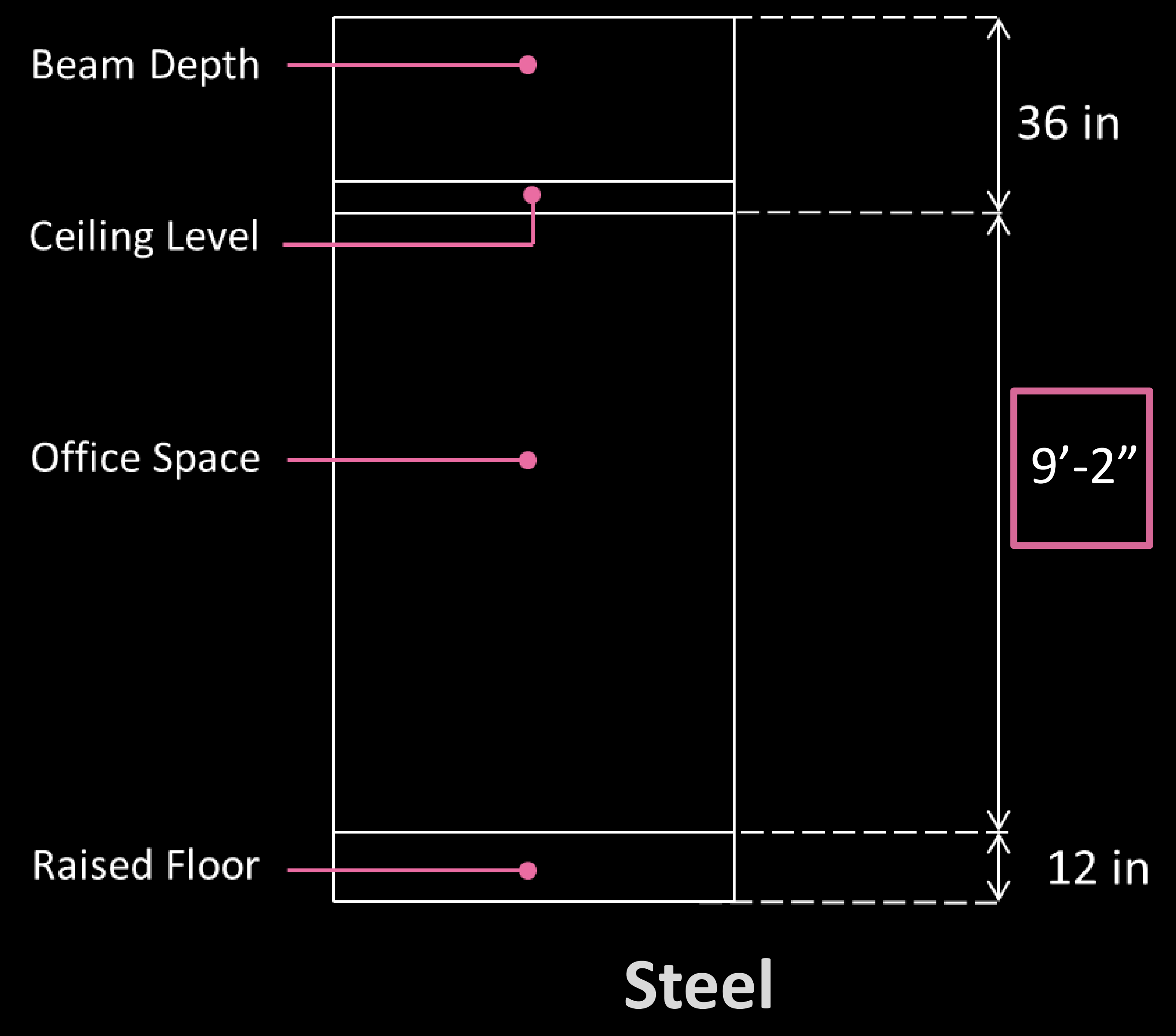
Floor-to-Ceiling Height

1'-6" Decrease in floor-to-ceiling height





Construction Breadth

Concrete System Cost

- Cost information provided by Hines
- Concrete chosen because it was cheaper than steel system
- Approximately $61 per SF

Original Concrete Structure Cost Summary	
Cost Per SF	$ 61.46
Structural Square Footage	462,301 SF
% General Conditions	14%
Total Original Structure Cost	$ 28,413,000
General Conditions Cost	$ 3,978,000
Original Structure Cost w/ out General Conditions	$ 24,435,000

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Steel System Cost

- Based on cost information from RS Means 2009
- Approximately $65 per SF

Total Steel Structure Cost (2009 RS Means)	
Item	Cost
Concrete on Metal Deck	$ 3,050,000
Structural Steel Framing	$ 9,052,000
Shear Walls	$ 4,310,000
Foundation Walls	$ 1,929,000
Lower Level Concrete Slabs	$ 2,796,000
Lower Level Concrete Columns	$ 198,000
Mat Foundation	$ 4,055,000
Total Cost	$ 25,391,000
Final Modified Cost	$ 30,072,000

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Cost Comparison

- 23 % Increase in cost for steel system
- Validates original decision by designers to design structure in concrete

Final Cost Comparison	
Original Concrete Structure Cost	$ 24,435,000
New Steel Structure Cost	$ 30,072,000
% Increase in Cost	23%

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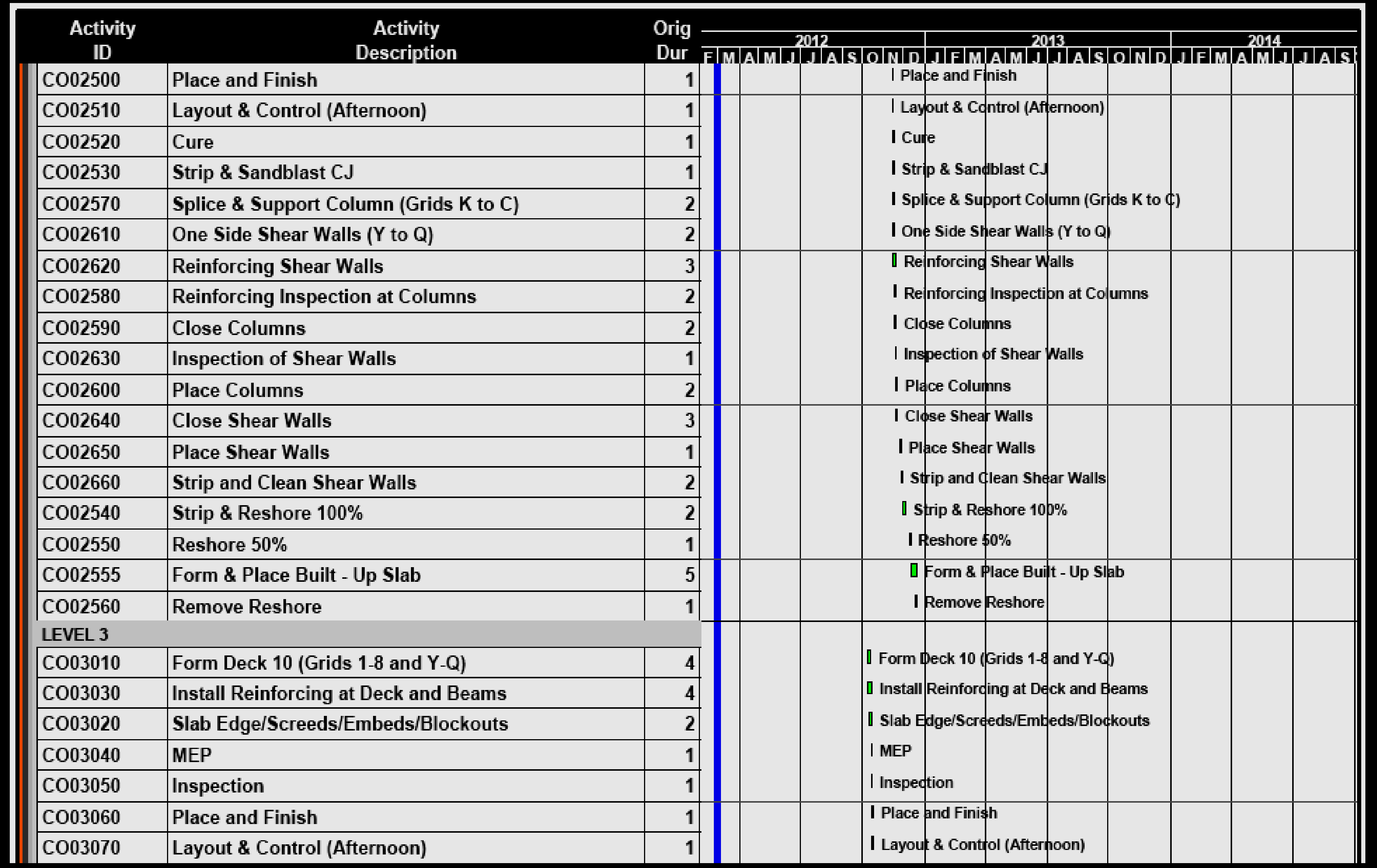
Concrete System Schedule

- Schedule information provided by Hines
- Superstructure duration | 240 days



Activity ID	Activity Description	Orig Dur
CO02500	Place and Finish	1
CO02510	Layout & Control (Afternoon)	1
CO02520	Cure	1
CO02530	Strip & Sandblast CJ	1
CO02570	Splice & Support Column (Grids K to C)	2
CO02610	One Side Shear Walls (Y to Q)	2
CO02620	Reinforcing Shear Walls	3
CO02580	Reinforcing Inspection at Columns	2
CO02590	Close Columns	2
CO02630	Inspection of Shear Walls	1
CO02600	Place Columns	2
CO02640	Close Shear Walls	3
CO02650	Place Shear Walls	1
CO02660	Strip and Clean Shear Walls	2
CO02540	Strip & Reshore 100%	2
CO02550	Reshore 50%	1
CO02555	Form & Place Built - Up Slab	5
CO02560	Remove Reshore	1
LEVEL 3		
CO03010	Form Deck 10 (Grids 1-8 and Y-Q)	4
CO03030	Install Reinforcing at Deck and Beams	4
CO03020	Slab Edge/Screeds/Embeds/Blockouts	2
CO03040	MEP	1
CO03050	Inspection	1
CO03060	Place and Finish	1
CO03070	Layout & Control (Afternoon)	1

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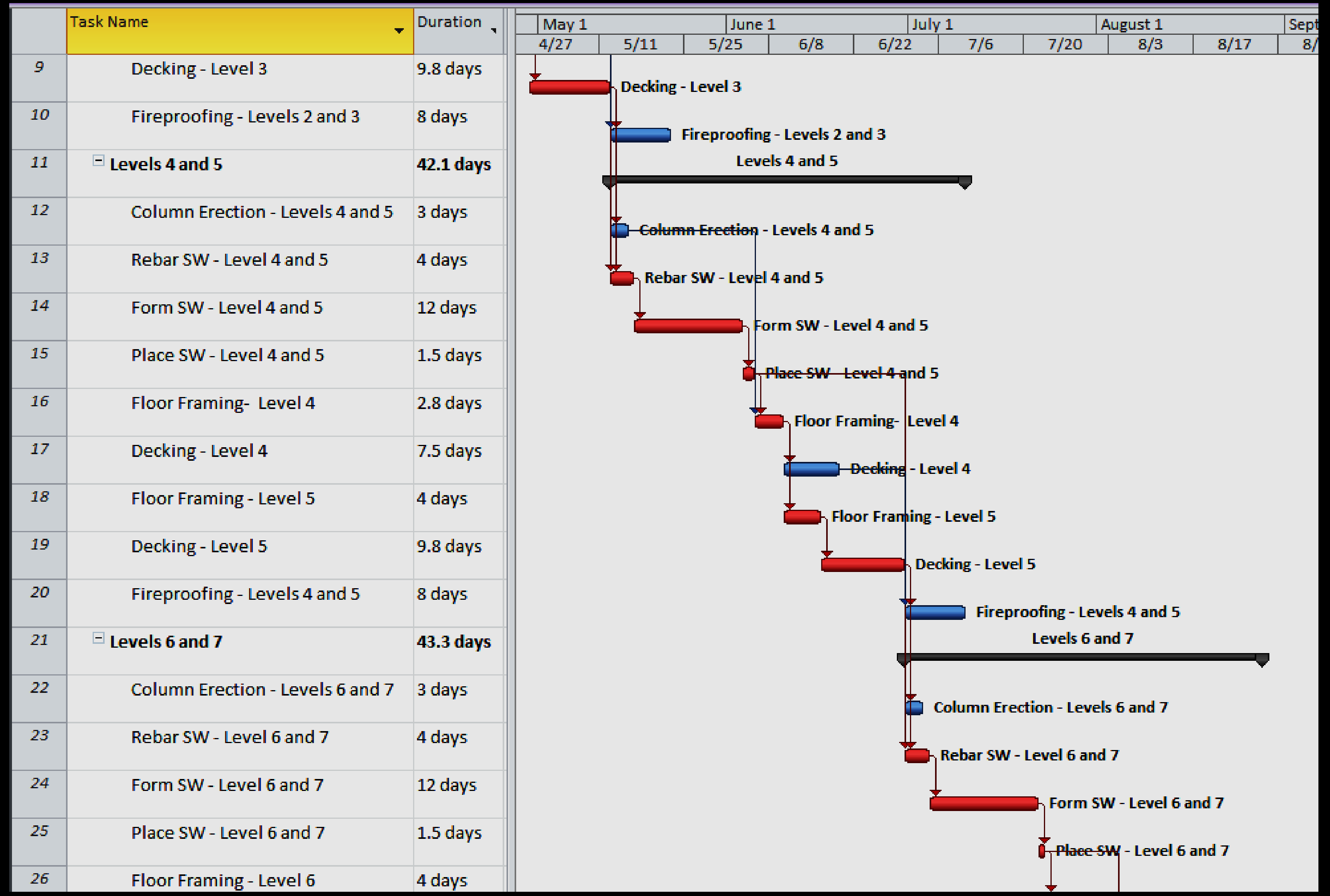
  - Moment Frames
  - Shear Walls
- Architecture Breadth
- **Construction Breadth**
- Conclusions

Steel System Schedule

- Schedule produced in Microsoft Project
- Durations from RS Means 2009
- Superstructure duration | 230 days



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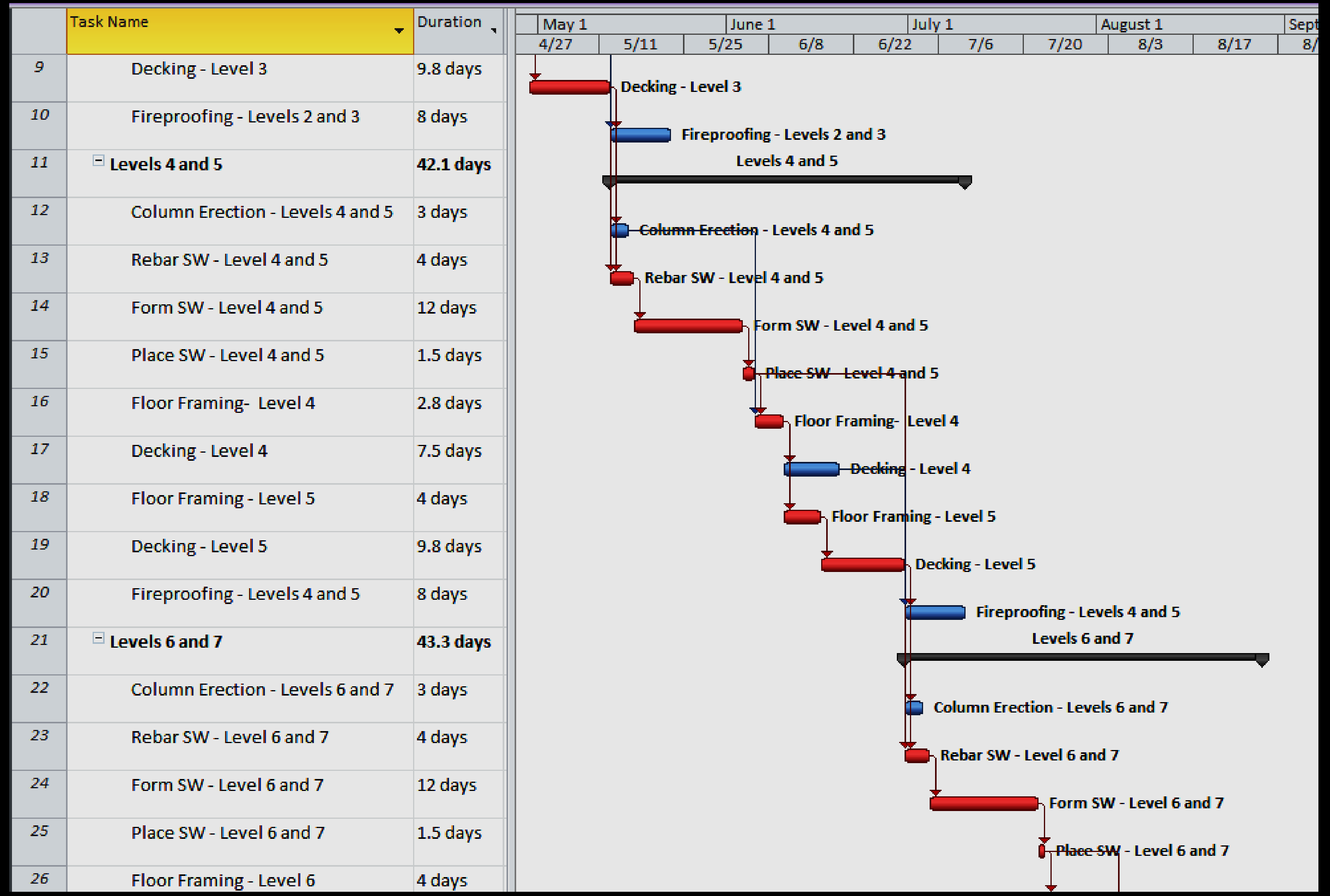
Schedule Comparison

- Only 2 weeks time savings
- Not worth the 23% cost increase
- If time savings were more significant, cost increase may have been offset



Conclusions

- Designed a feasible steel gravity system with vibration reducing characteristics
- Designed special steel moment frames
- Eliminated torsional irregularity
- Reduced floor-to-ceiling heights
- Increased cost for steel structure is not offset by reduction in project schedule

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Acknowledgements

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Benjamin Barben

My loving family, boyfriend, friends, and classmates

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Questions and Comments?