*Structural Design in an*

# Adaptive Reuse Project

## A look at the structure behind 246 West 17$^{th}$ Street New York, NY

Presented by:
Alissa Popovich

Faculty Consultant:
Dr. Ali Memari

The Department of Architectural Engineering
at The Pennsylvania State University

April 13, 2009

246 West 17th Street
New York, NY

## Presentation Outline



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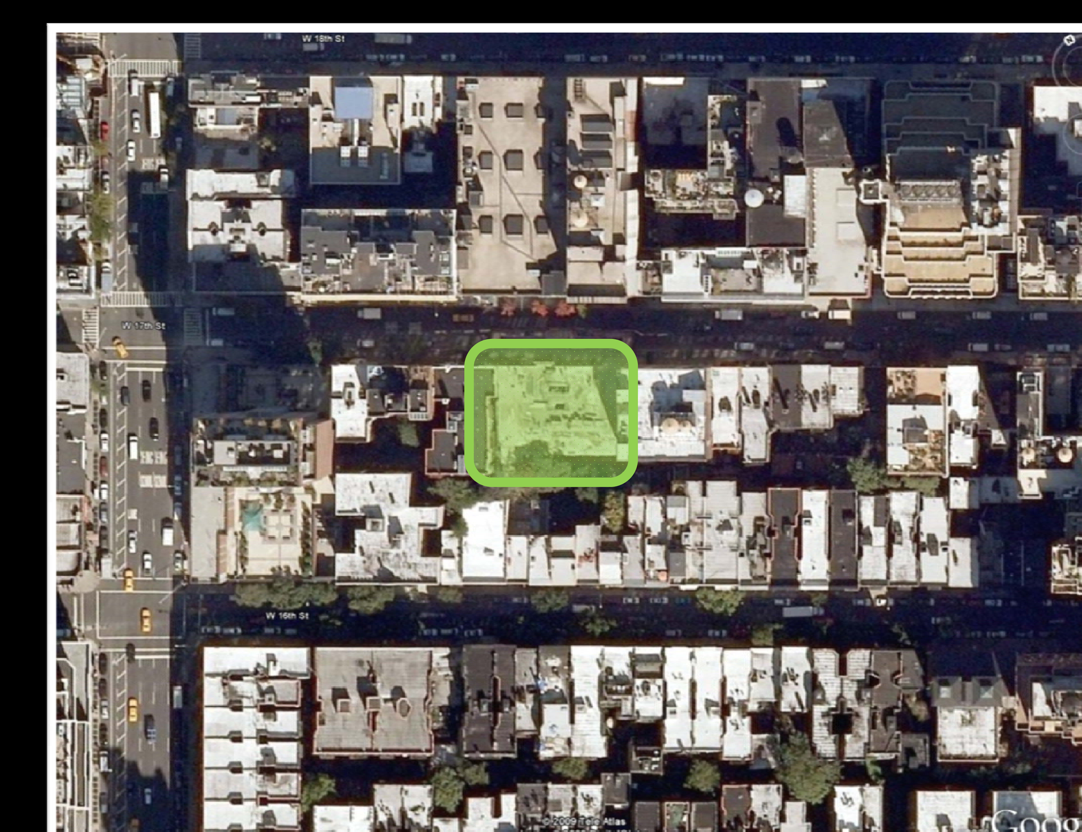
## Project Introduction

Location 236 West 17th Street, New York, NY
Occupancy Type Residential (34 Condominium Units)

Owner Anthony Leichter
Structural Engineers Robert Silman Associates
Architect Rawlings Architects

Building Height 131.0' feet (10 stories)
Building Area 54,000 square feet
Construction Cost $16.5 million



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## Existing Conditions

Adaptive Reuse +
New Construction

The building was once a 3-story brick garage from 1925

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## Presentation Outline



## Existing Conditions

**Historic Structure**

- Steel framing (30ksi)
- Mass masonry exterior bearing walls
- 8” draped-mesh slab system (860psi)
- Typical bay size: 20’-8” x 35’-6”

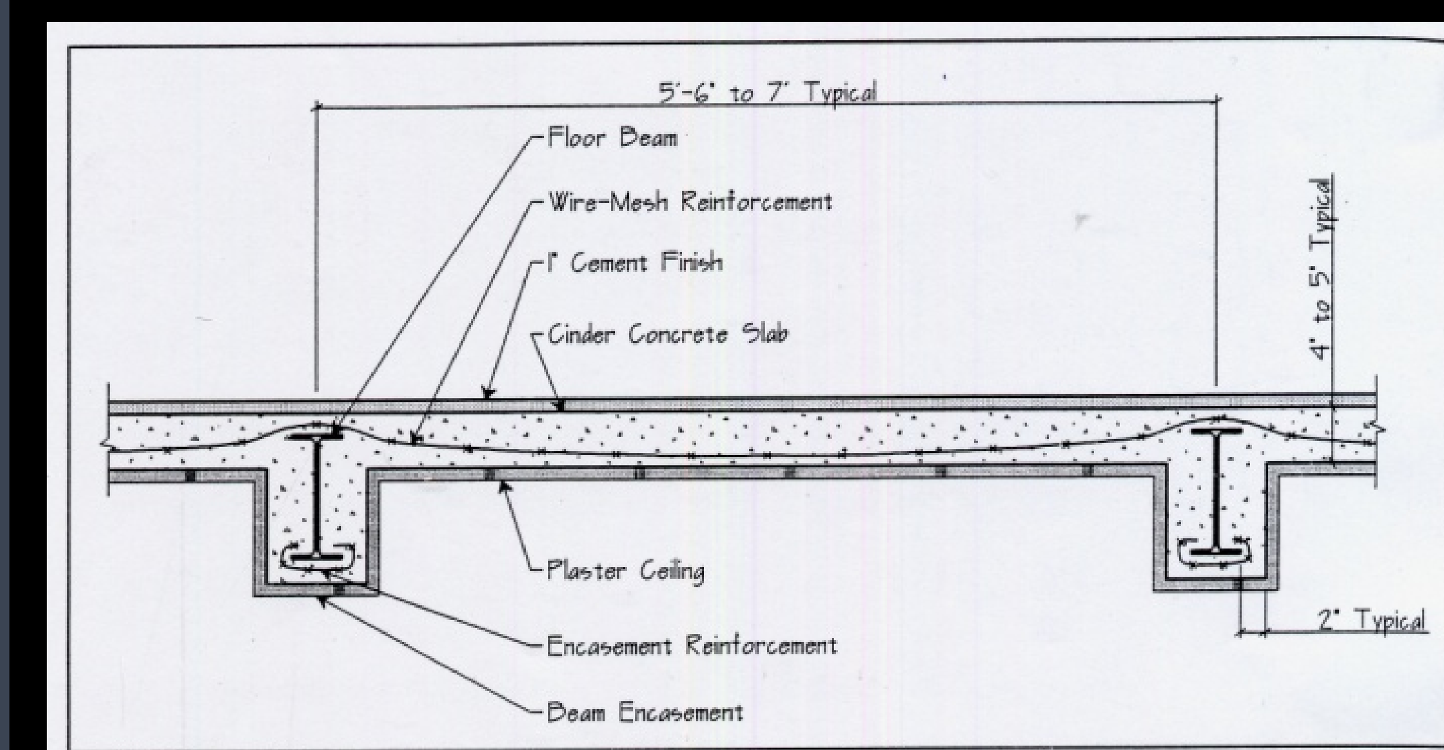


Image taken from *Historic Building Construction* by Donald Friedman

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## Presentation Outline

- Project Introduction
- Existing Conditions
- Proposal & Design Goals
- Structural Depth Study
- Construction Cost Study
- Conclusions & Recommendations
- Acknowledgements
- Questions

## Existing Conditions

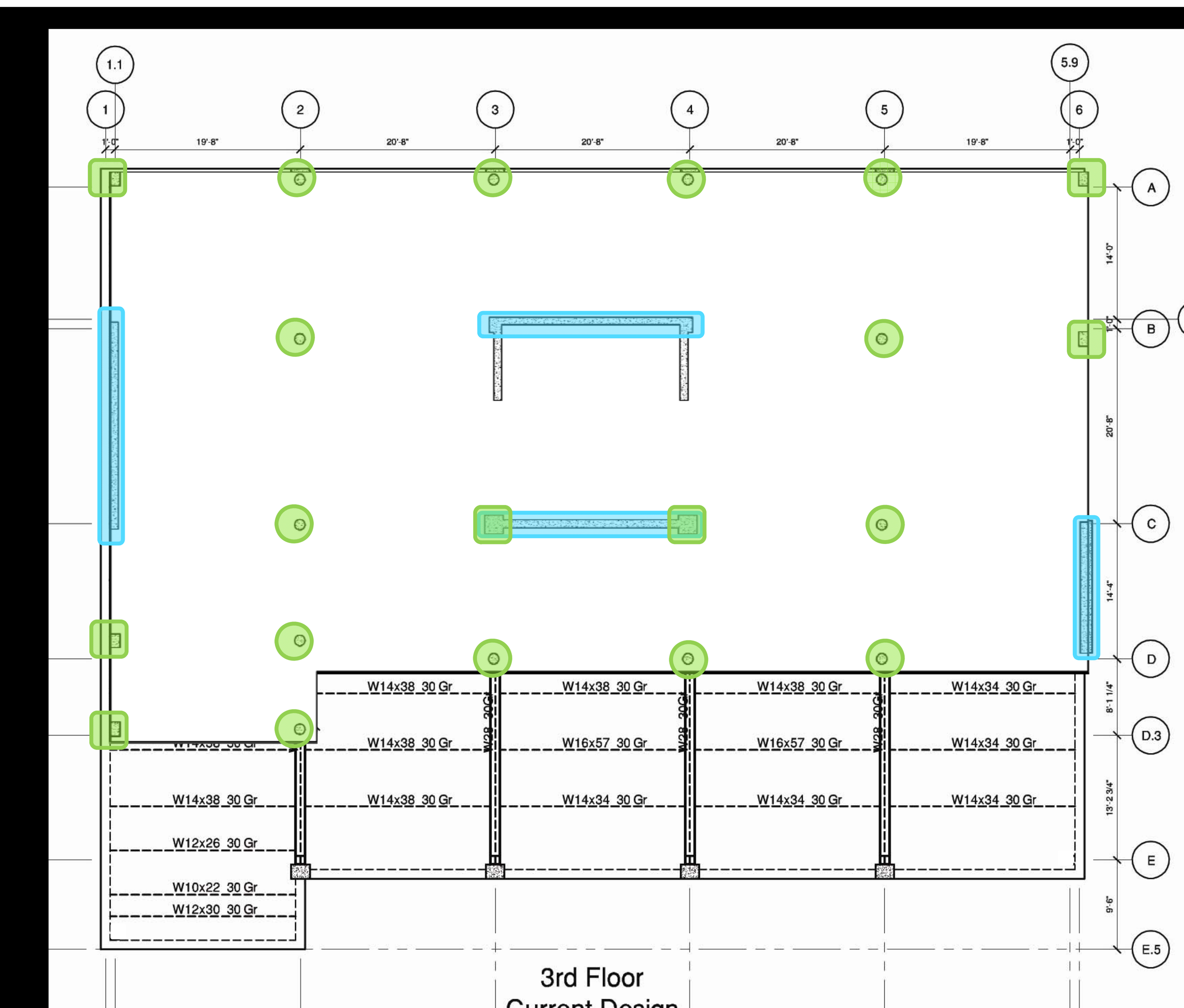
**Historic Structure**

- Steel framing (30ksi)
- Mass masonry exterior bearing walls
- 8” draped-mesh slab system (860psi)
- Typical bay size: 20’-8” x 35’-6”

**Current Structure**

- 8” two-way flat-plate concrete slab system
- Circular and rectangular gravity columns
- 2 (10”) concrete shear walls in each direction

- Foundation consists of 3’-10” thick mat slab and spread footings



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## Presentation Outline



## Proposal & Design Goals

**Problem Statement**

The seven stories of concrete structure added atop the historic steel and masonry structure contribute an extensive amount of weight to the building.

**Proposed Solution**

Redesign the concrete addition as a steel to decrease the weight on the historic system.

**Design Goals**

- More efficient reinforcing of historic members at transfer level
- Decrease size and/or depth of foundation
- Incorporate historic steel members into lateral system

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## Structural Depth Study

**Current Loads**

- Based on the requirements within the New York City Building Code (NYCBC)

**Proposed Gravity Loads**

- Live loads based on ASCE7-05 minimum distributed load requirements
- Dead loads based on requirements within ASCE7-05 and known values of material weights

**Proposed Lateral Loads**

- Wind and seismic loads determined in RAM Structural System in accordance ASCE7-05

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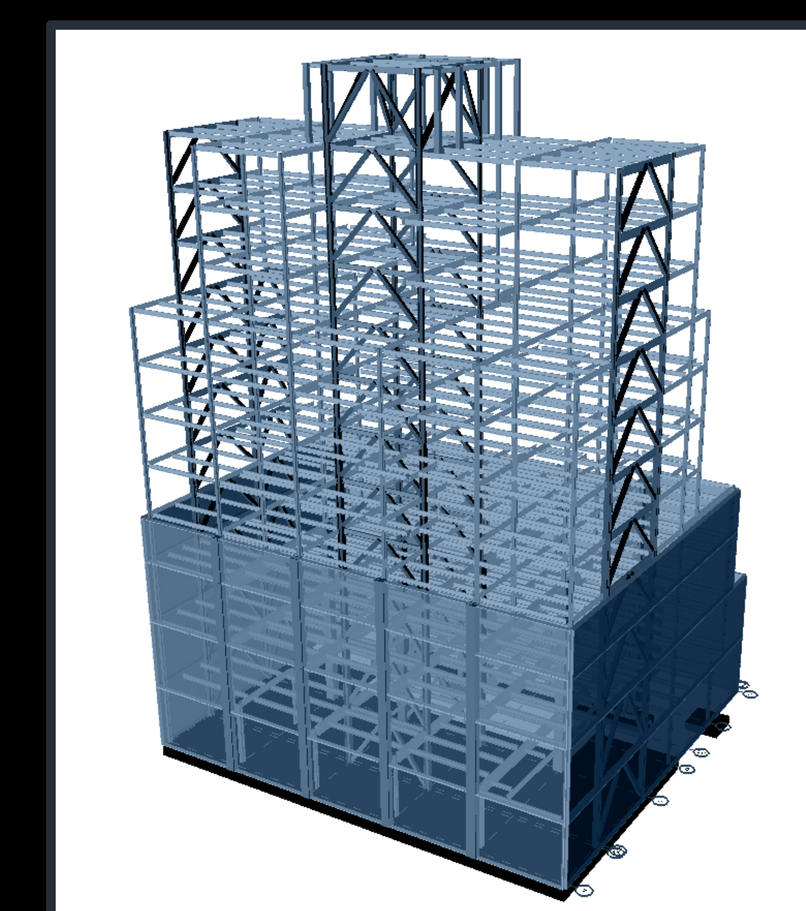
## Structural Depth Study

Computer Modeling using RAM SS

- All diaphragms modeled as rigid
- Assumed adequate connections and load transfer between new and historic structure
- Assumed that all columns be braced at floor levels
- Masonry modeled with cracked section property of 0.6
- Story forces placed at 5% eccentricity to account for accidental torsion
- Historic steel modeled using conservative and comparable modern sections based on weight, depth, and stiffness



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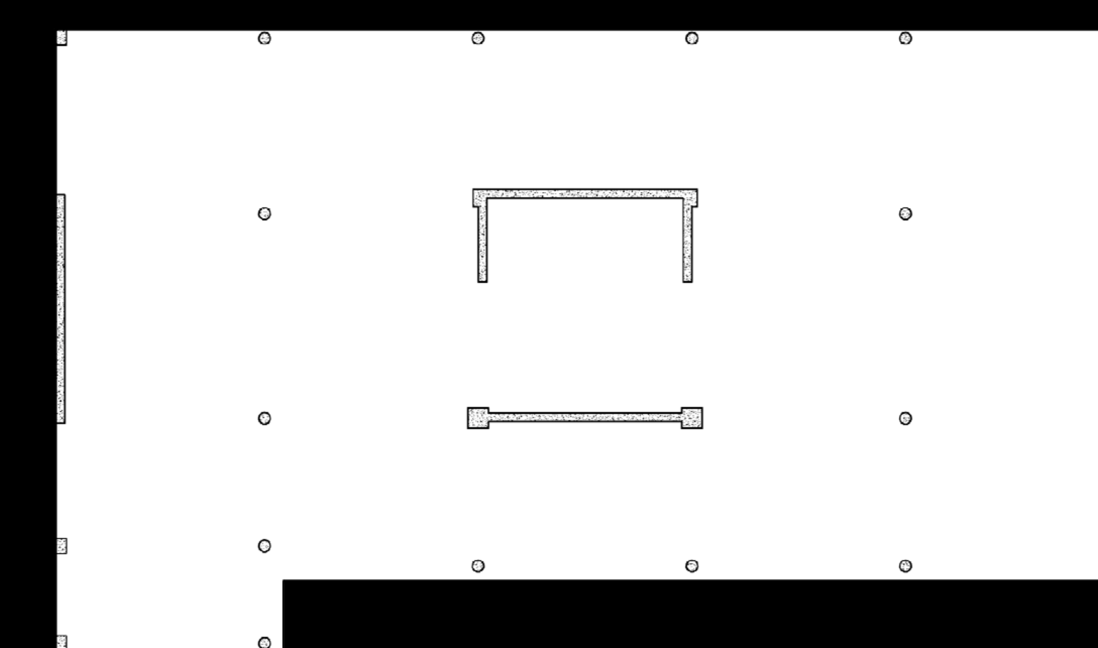
## Structural Depth Study

Gravity System Design

- Frame layout based on existing column grid to minimize effects on interior architecture



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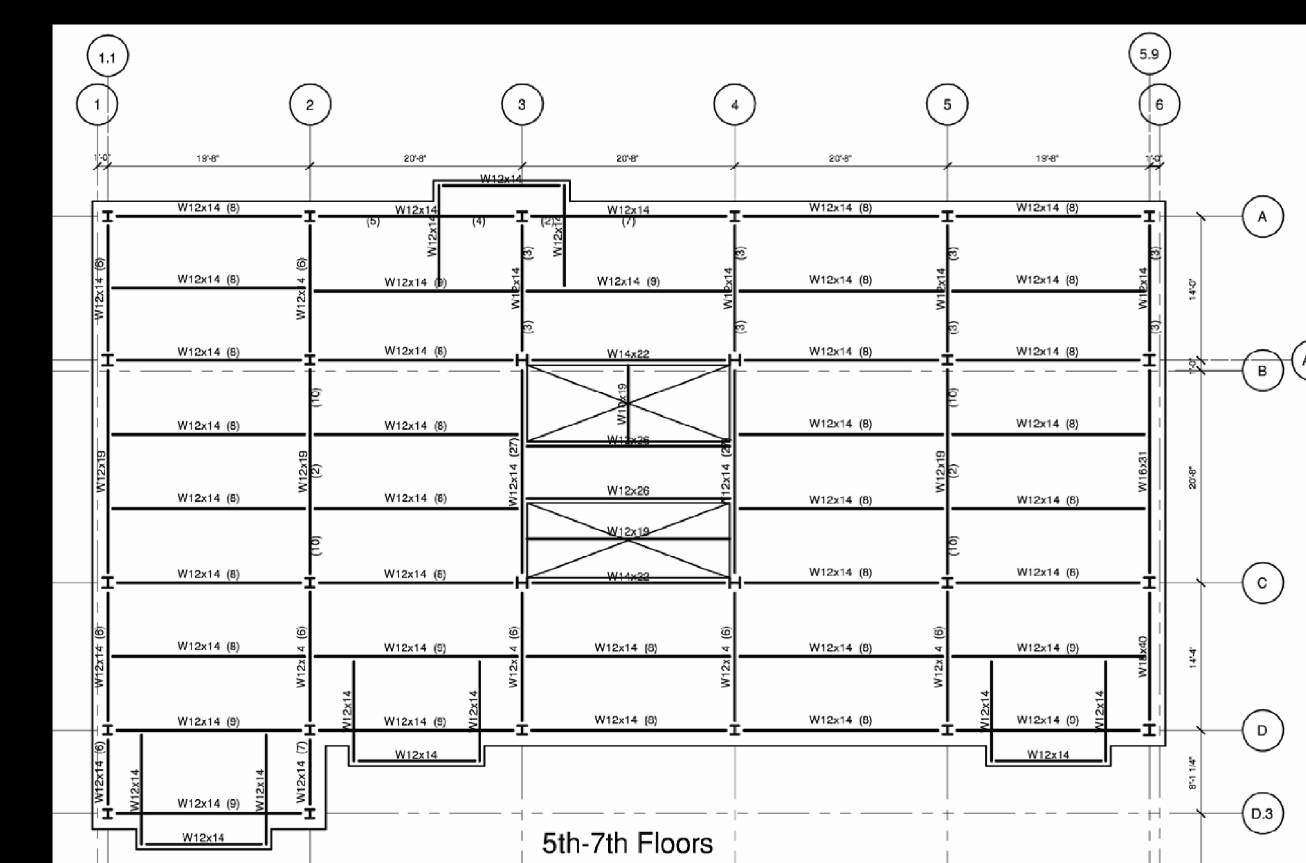
## Structural Depth Study

Gravity System Design

- Frame layout based on existing column grid to minimize effects on interior architecture
- Slab and deck selection based on span and fireproofing requirements:
  - 6” lightweight concrete slab with
  - 3” Lok-Floor composite deck s
- Steel sized in accordance with the *AISC Manual of Steel Construction* LRFD design methods
  - Composite design of beams and girders found to be more efficient



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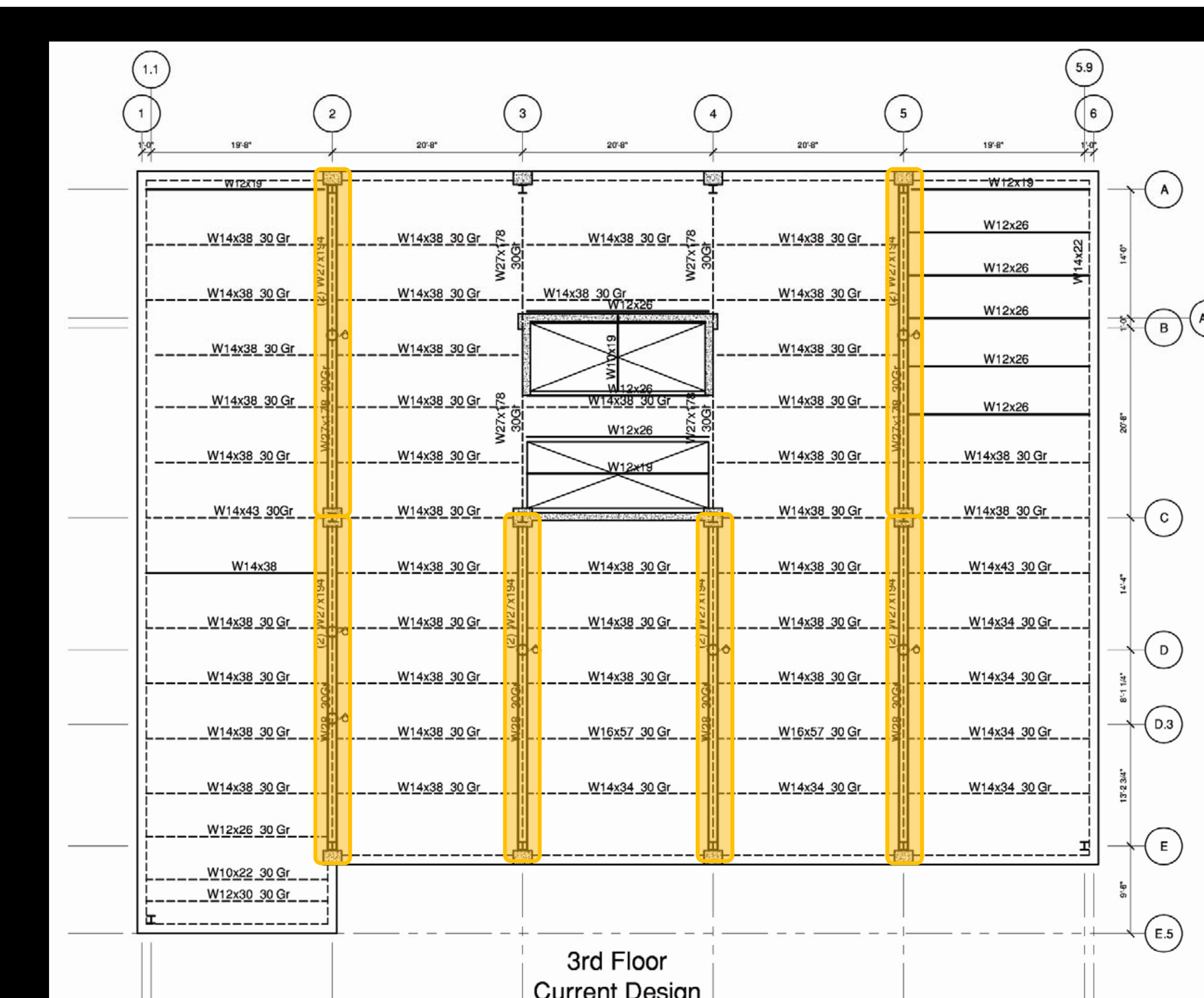
## Structural Depth Study

Member Reinforcement

At the 3rd floor transfer level:

- SIX girders to be reinforced in existing design



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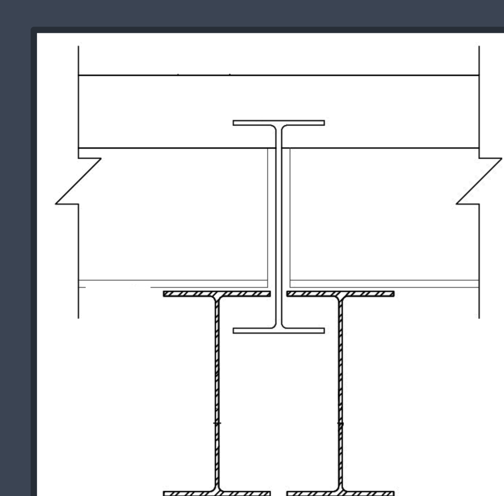
## Structural Depth Study

**Member Reinforcement**

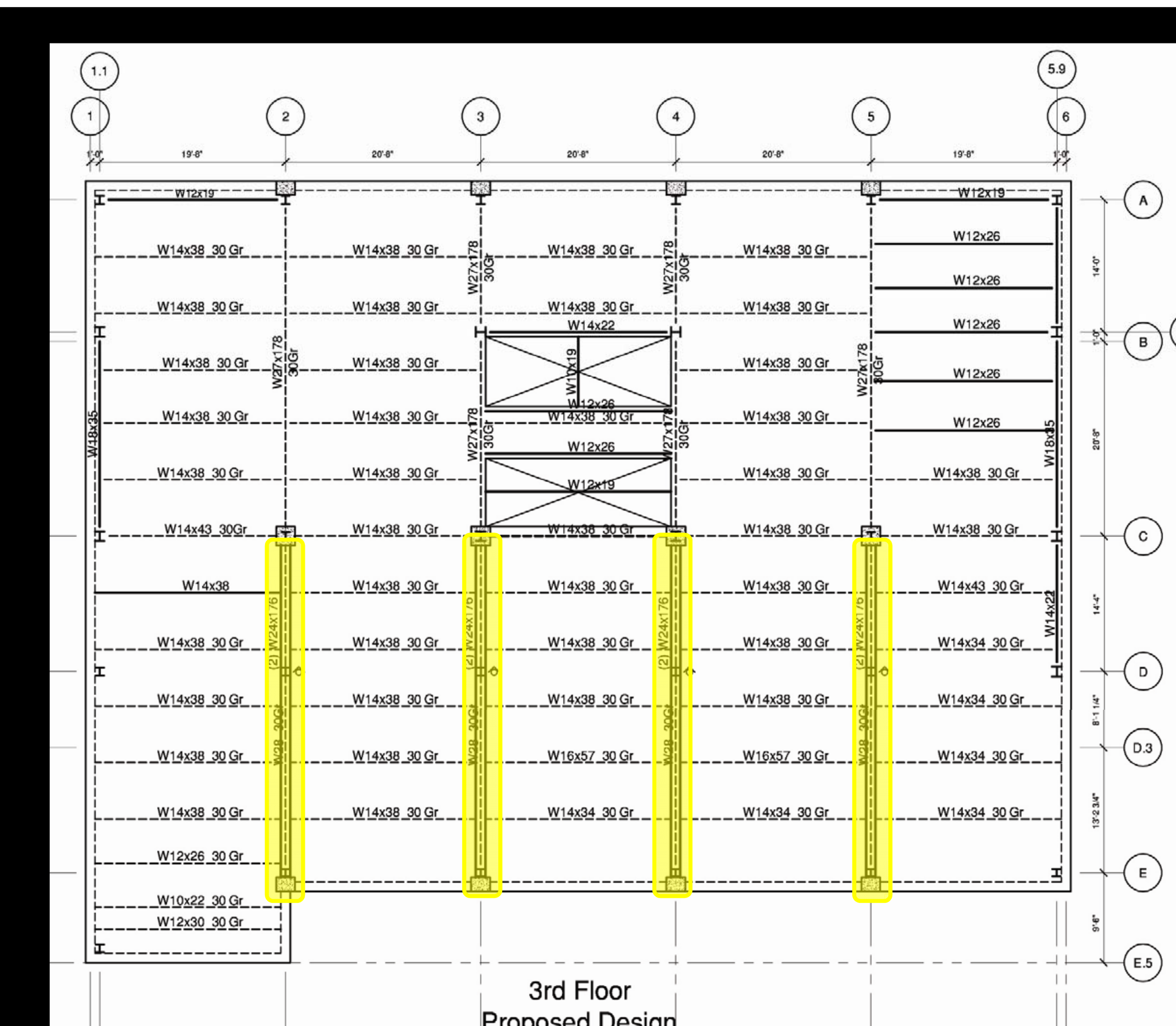


At the 3rd floor transfer level:

- SIX girders to be reinforced in existing design
- Only FOUR to be reinforced in proposed design

Reinforcement designed using plastic analysis

Old design: (2)W27x194
New design: (2)W24x176



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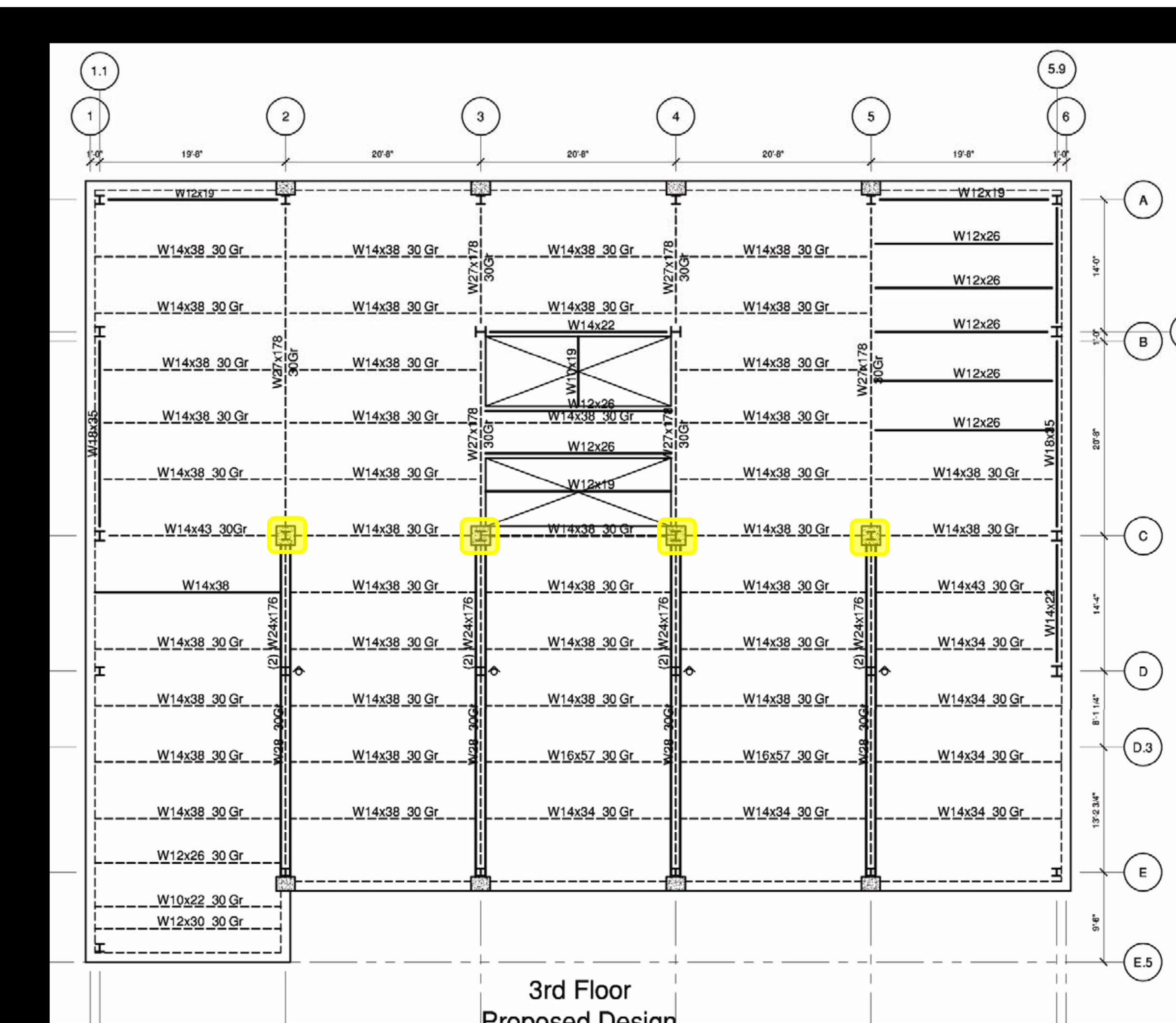
## Structural Depth Study

**Member Reinforcement**

Historic column reinforcement:

- 4 columns on each of the first 3 levels
- Frame geometry controlled initial column size
  - Continuous reinforcing required between stories



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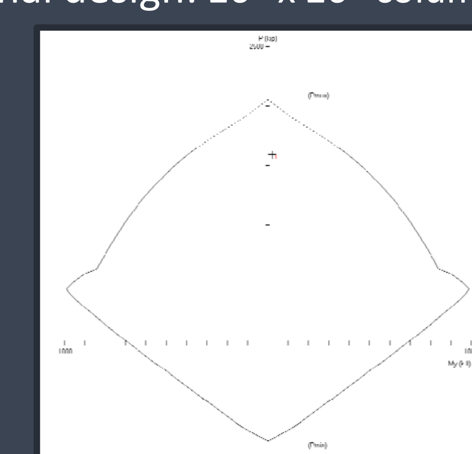
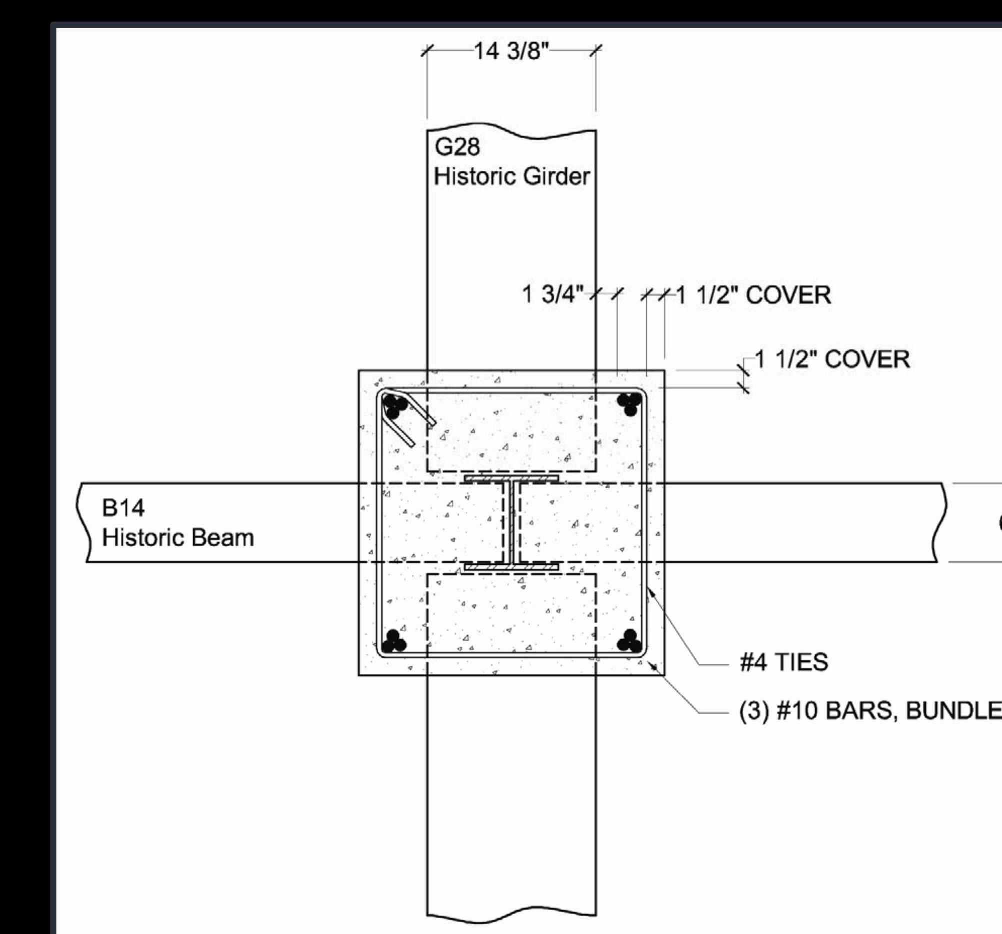
## Structural Depth Study

Member Reinforcement

Historic column reinforcement:

- 4 columns on each of the first 3 levels
- Frame geometry controlled initial column size
  Continuous reinforcing required between stories
- Final design: 26" x 26" column (4ksi)





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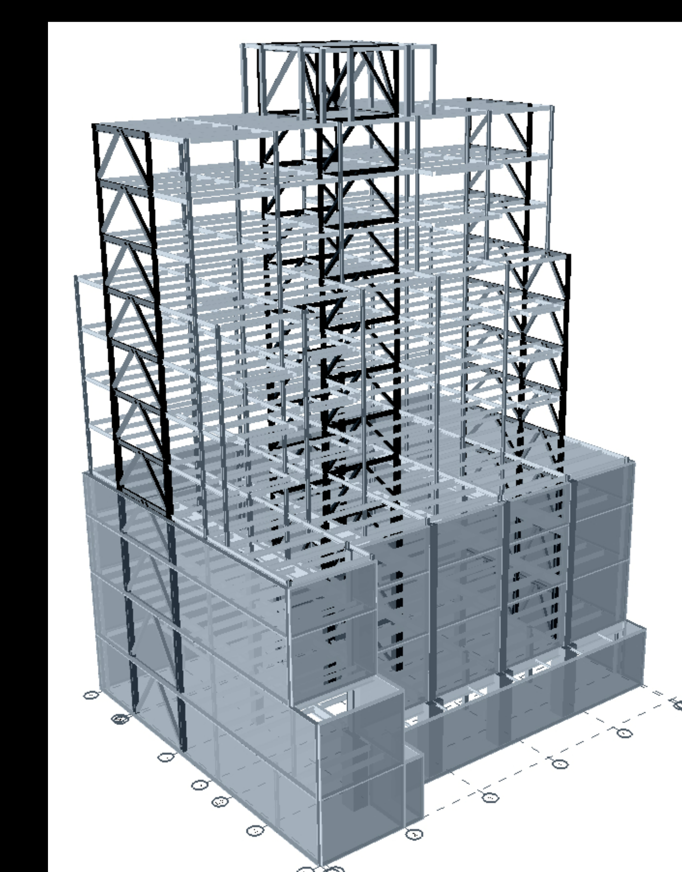
## Presentation Outline

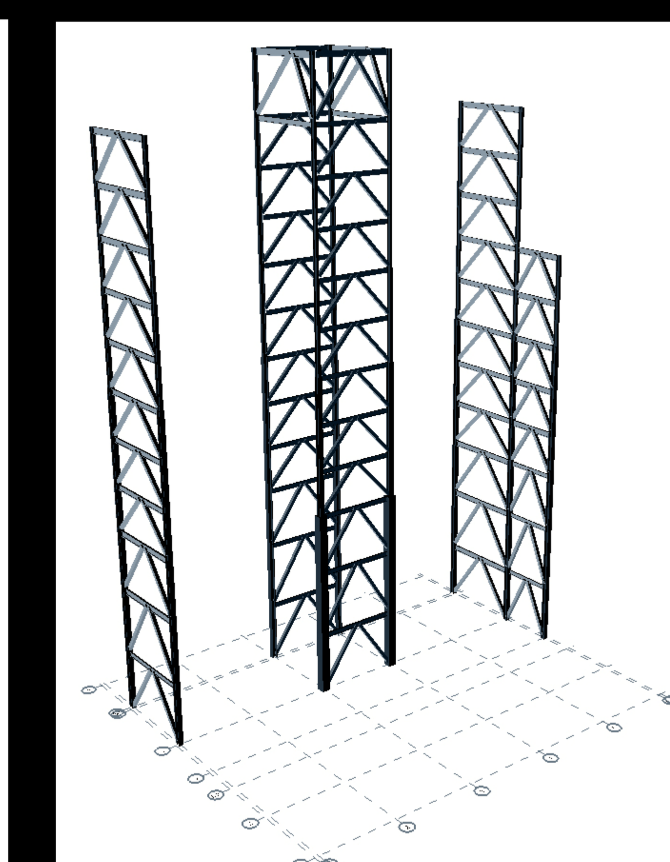


## Structural Depth Study

Lateral System Design

- Drift limitations:
  - L/600 for historic stories
  - L/400 for modern stories
  - 1-1/8" overall deflection at 6$^{th}$ floor level in the E-W direction due to seismic joint
- Chevron braces chosen as lateral force resisting members
  - 2 frames designed in each direction





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# Presentation Outline



# Structural Depth Study

## Lateral System Design

- Design process in RAM SS:
  - Brace, column, and beam design for lateral strength requirements
  - Brace design for lateral deflection limitations
    * Deflection controlled the design
  - Column design for lateral deflection limitations
  - Brace, column, and beam check based on lateral strength requirements
  - Beam check and re-design based gravity requirements
- Seismic drift amplification factor
  - $C_d = 3.25$

| DRIFT DATA | | | Wind Drifts [in] | | | | Seismic Drifts [in] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| X-DIRECTION (E-W) | | | Total Drift | | Story Drift | Allowable Story Drift | Total Drift | | | Story Drift | Allowable Story Drift |
| Level | Total Ht. | Story Ht. | Load Case | Δ Wind | Δ Story | h/400, h/600 | Load Case | Δ Elastic | Δ Amplified | Δ Story | $0.020h_{sx}$ |
| BH | 134.486 | 14.500 | W1, W2 | ***1.869*** | **0.230** | **0.44** | E2 | 0.684 | ***2.223*** | **0.286** | **3.48** |
| Roof | 119.986 | 11.167 | W1, W2 | *1.639* | **0.182** | **0.34** | E2 | 0.596 | *1.937* | **0.224** | **2.68** |
| 10 | 108.819 | 11.167 | W1, W2 | *1.457* | **0.184** | **0.34** | E2 | 0.527 | *1.713* | **0.228** | **2.68** |
| 9 | 97.652 | 11.167 | W1, W2 | *1.273* | **0.181** | **0.34** | E2 | 0.457 | *1.485* | **0.224** | **2.68** |
| 8 | 86.485 | 11.167 | W1, W2 | *1.092* | **0.177** | **0.34** | E2 | 0.388 | *1.261* | **0.218** | **2.68** |
| 7 | 75.318 | 11.167 | W1, W2 | *0.915* | **0.167** | **0.34** | E2 | 0.321 | *1.043* | **0.205** | **2.68** |
| 6 | 64.151 | 11.167 | W1, W2 | *0.748* | **0.161** | **0.34** | E2 | 0.258 | *0.839* | **0.189** | **2.68** |
| 5 | 52.984 | 11.167 | W1, W2 | *0.587* | **0.149** | **0.34** | E2 | 0.200 | *0.650* | **0.172** | **2.68** |
| 4 | 41.817 | 11.167 | W1, W2 | *0.438* | **0.138** | **0.22** | E2 | 0.147 | *0.478* | **0.156** | **2.68** |
| 3 | 30.65 | 14.400 | W1, W2 | *0.300* | **0.156** | **0.29** | E2 | 0.099 | *0.322* | **0.172** | **3.46** |
| 2 | 16.25 | 16.250 | W1, W2 | *0.144* | **0.144** | **0.33** | E2 | 0.046 | *0.150* | **0.150** | **3.90** |
| 1 | 0 | 0 | N/A | *0* | **0** | **0** | N/A | 0 | *0* | **0** | **0** |

W1 = Wind +X , W2 = Wind –X E2 = Earthquake +X

| DRIFT DATA | | | Wind Drifts [in] | | | | Seismic Drifts [in] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y-DIRECTION (N-S) | | | Total Drift | | Story Drift | Allowable Story Drift | Total Drift | | | Story Drift | Allowable Story Drift |
| Level | Total Ht. | Story Ht. | Load Case | Δ Wind | Δ Story | h/400, h/600 | Load Case | Δ Elastic | Δ Amplified | Δ Story | $0.020h_{sx}$ |
| BH | 134.486 | 14.500 | W3, W4 | ***1.629*** | **0.014** | **0.44** | E4 | 1.979 | ***6.412*** | **0.075** | **3.48** |
| Roof | 119.986 | 11.167 | W3, W4 | *1.615* | **0.215** | **0.34** | E4 | 1.956 | *6.337* | **0.862** | **2.68** |
| 10 | 108.819 | 11.167 | W3, W4 | *1.400* | **0.223** | **0.34** | E4 | 1.690 | *5.475* | **0.891** | **2.68** |
| 9 | 97.652 | 11.167 | W3, W4 | *1.177* | **0.214** | **0.34** | E4 | 1.415 | *4.585* | **0.836** | **2.68** |
| 8 | 86.485 | 11.167 | W3, W4 | *0.963* | **0.206** | **0.34** | E4 | 1.157 | *3.749* | **0.810** | **2.68** |
| 7 | 75.318 | 11.167 | W3, W4 | *0.757* | **0.202** | **0.34** | E4 | 0.907 | *2.939* | **0.797** | **2.68** |
| 6 | 64.151 | 11.167 | W3, W4 | *0.555* | **0.193** | **0.34** | E4 | 0.661 | *2.142* | **0.755** | **2.68** |
| 5 | 52.984 | 11.167 | W3, W4 | *0.362* | **0.145** | **0.34** | E4 | 0.428 | *1.387* | **0.687** | **2.68** |
| 4 | 41.817 | 11.167 | W3, W4 | *0.217* | **0.177** | **0.22** | E4 | 0.216 | *0.700* | **0.564** | **2.68** |
| 3 | 30.65 | 14.400 | W3, W4 | *0.040* | **0.024** | **0.29** | E4 | 0.042 | *0.136* | **0.075** | **3.46** |
| 2 | 16.25 | 16.250 | W3, W4 | *0.016* | **0.016** | **0.33** | E4 | 0.019 | *0.062* | **0.062** | **3.90** |
| 1 | 0 | 0 | N/A | *0* | **0** | **0** | N/A | 0 | *0* | **0** | **0** |

W1 = Wind +Y , W2 = Wind –Y E4 = Earthquake +Y

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# Presentation Outline

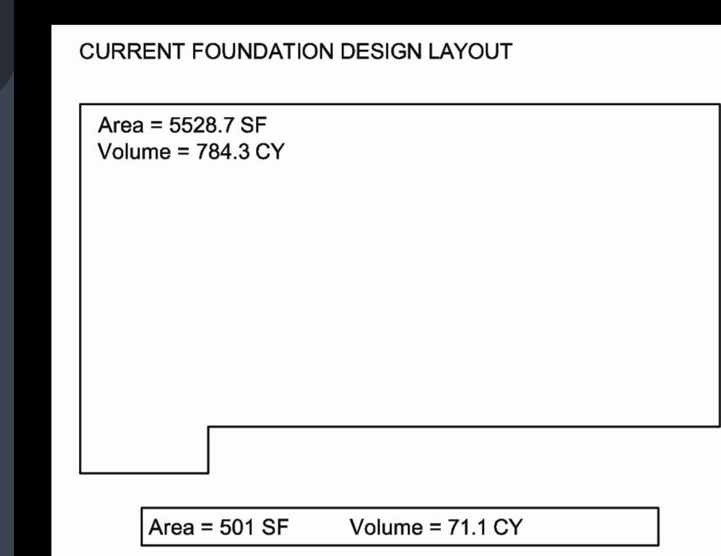


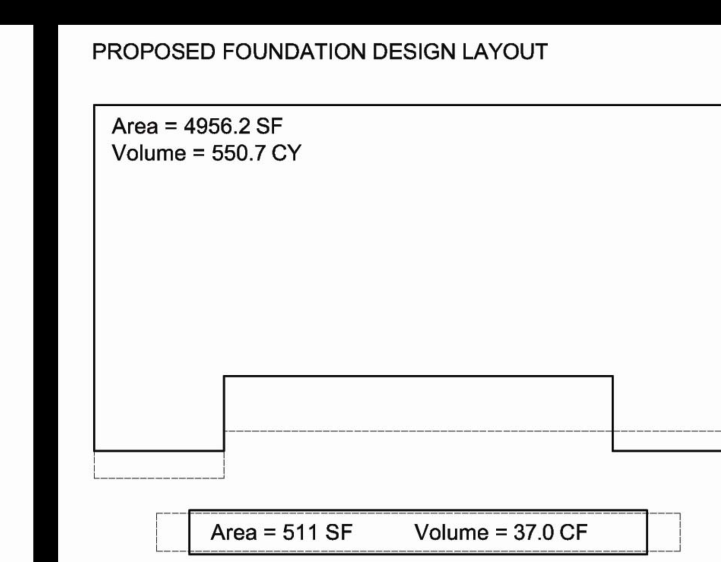
# Structural Depth Study

**Foundation Impacts**

- Current design
  - 3'-10" mat slab
  - 3'-10" continuous spread footing
- Proposed design
  - 3' mat slab (10" decrease)
  - 2' continuous spread footing (22" decrease)

| Foundation Design Comparison | | | |
|---|---|---|---|
| **Mat Slab** | Current Design | Proposed Design | Difference |
| Surface Area [SF] | 5528.7 | 4956.2 | -572.5 |
| Thickness [inches] | 46 | 36.0 | -10.0 |
| Concrete Volume [CY] | 784.3 | **550.7** | -233.6 |
| **Continuous Footing** | Current Design | Proposed Design | Difference |
| Surface Area [SF] | 501 | 511 | 10.0 |
| Thickness [inches] | 46 | 24.0 | -22.0 |
| Concrete Volume [CY] | 71.1 | **37.9** | -33.2 |
| Total Conc. Volume [CY] | 855.3 | **588.5** | -266.8 |



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## Construction Cost Study

Cost Considerations

- Materials
  - Concrete (foundations, structural system)
  - Steel (rebar, reinforcing members)
- Concrete labor
  - Formwork
  - Placement (concrete, rebar)
  - Finishing
- Steel labor
  - Welding
  - Bolted connections

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## Construction Cost Study

Estimated Savings per System

- Cost values based on relative savings seen in labor and materials associated with the system change
- Total savings amount to 7.6% of overall project cost

| Current (Concrete) System | Proposed (Steel) System | Savings |
|---|---|---|
| Foundation Cost<br>$202,133 | Foundation Cost<br>$140,687 | In Foundations<br>$61,446 |
| Superstructure Cost<br>$2,423,497 | Superstructure Cost<br>$1,235,295 | In Superstructure<br>$1,188,202 |
| Total Cost<br>$16,500,000 | Total Cost<br>$15,250,352 | In Total Cost<br>$1,249,648 |

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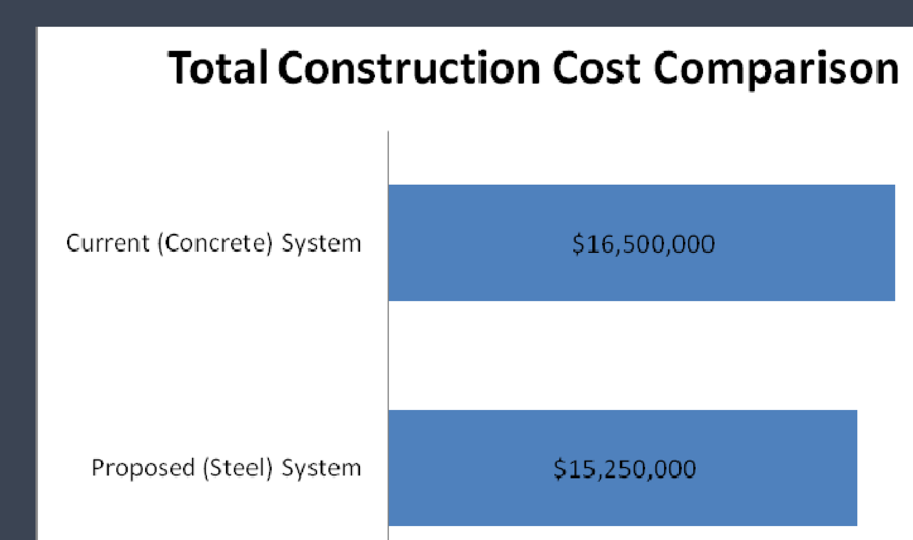
## Construction Cost Study

Total Cost Comparison

- Overall cost estimates based on relative cost savings



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## Conclusions & Recommendations

**Structural Design**

Structural design goals attained:

- ✓ Historic members utilized in the lateral system
- ✓ Reduced transfer beam reinforcing member size
- ✓ Decreased foundation depths

**Construction Cost**

Construction cost findings:

- ✓ Decreased foundation depth means less excavation and foundation material (cost savings)
- ✓ Fewer reinforced historic steel members means less associated labor and materials (cost savings)
- ✓ Overall estimated savings of $1.25 million (7.6%)

**Conclusion**

Recommend changing the structural system of the addition from concrete to steel

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- Dr. Ali Memari
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Rawlings Architects
- Ms. Kai Cheung

Pandiscio Co
- Mr. Sean Conway

Owner
- Mr. Anthony Leichter