The John Jay College Expansion Project
New York, NY

Michael Hopper – Structural Option
AE Senior Thesis 2009

Presentation Outline

- Project Information
- Existing Structural Systems
- Problem Statement and Solution
- Structural Design
- Architectural Studies
- Construction Studies
- Conclusions

Project Information

General Information

• Transform JJC of Criminal Justice into a 1-block urban campus
•Expansion to Existing Harren Hall
• 620,000 Square Feet
• $ 457 Million
• 14 Story Tower
• 5 story Podium connecting tower to Harren Hall
• Design calls for:
    • Grand Cascade
    • Landscaped Podium Roof
    • Prefabricated Curtain Wall System

Project Information

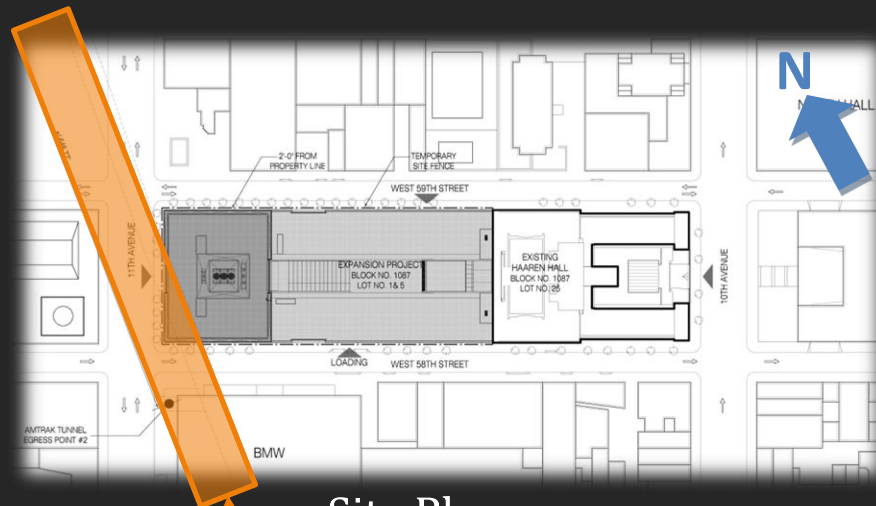
Project Location

- 11^{th} Avenue between 58^{th} and 59^{th} Street

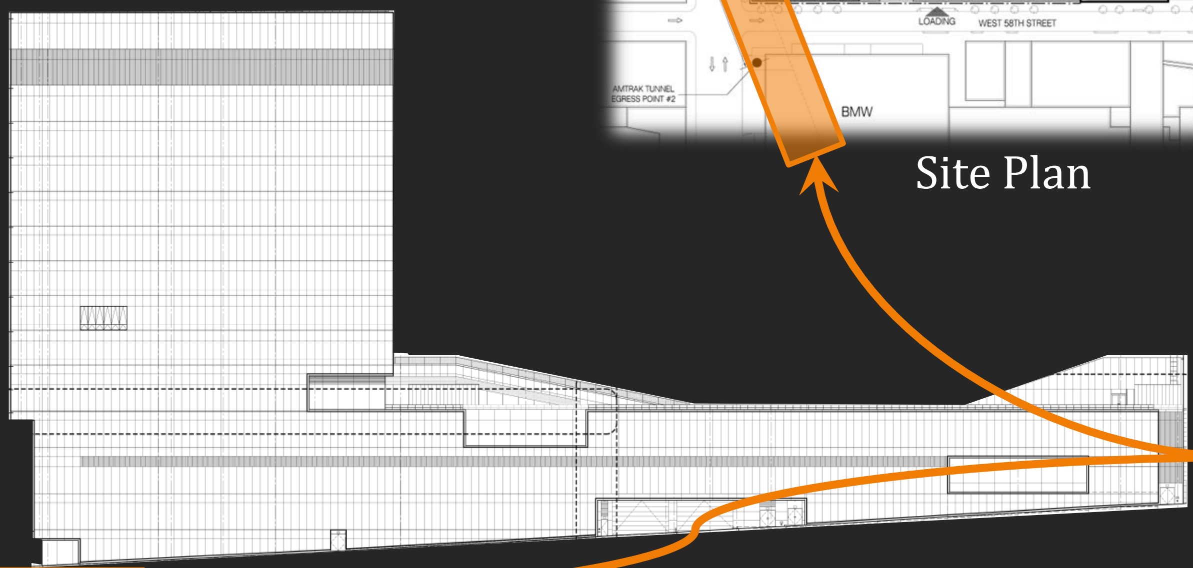
Project Information

Site Restriction

AMTRAK



Site Plan



South Elevation

Amtrak tracks pass beneath the tower!

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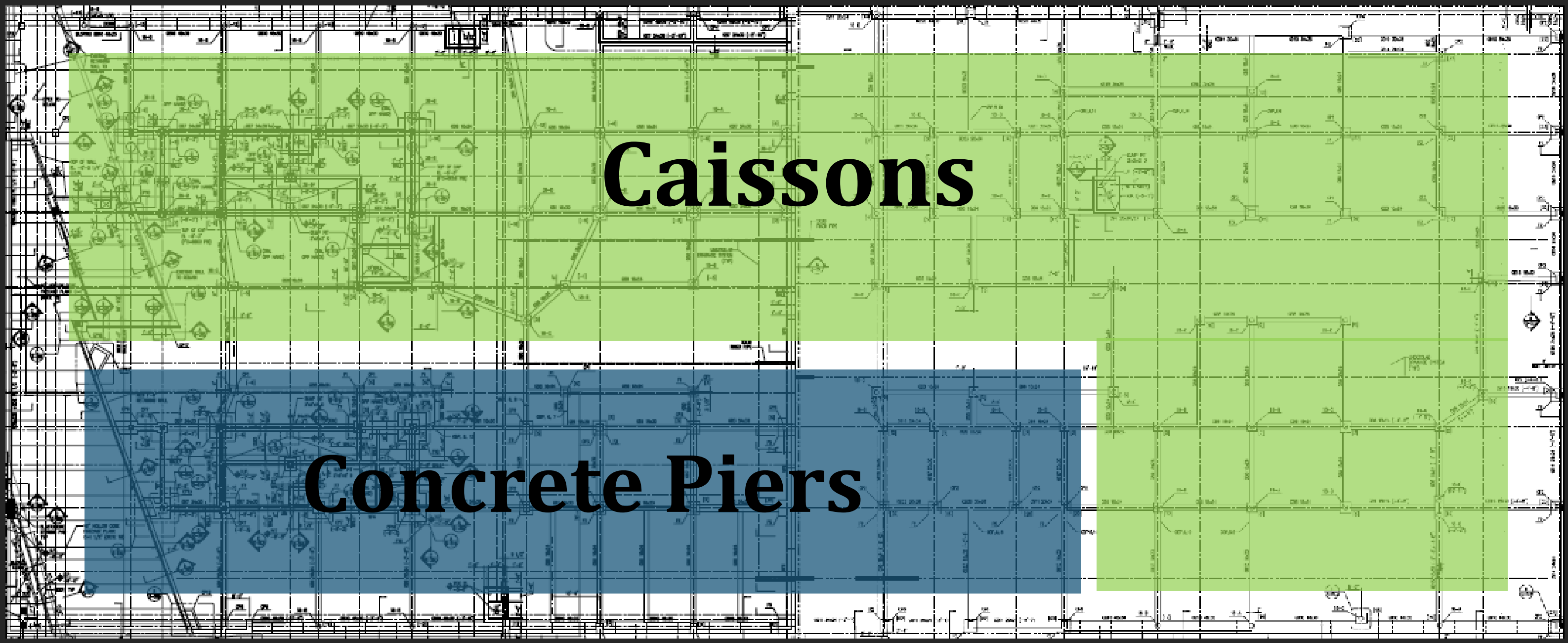
Existing Structural Systems

Foundation

- Reinforced Concrete Caissons
  - 18" to 36" diameter embedded up to 14' in bedrock
  - Encased w/ ½" thick steel tubing

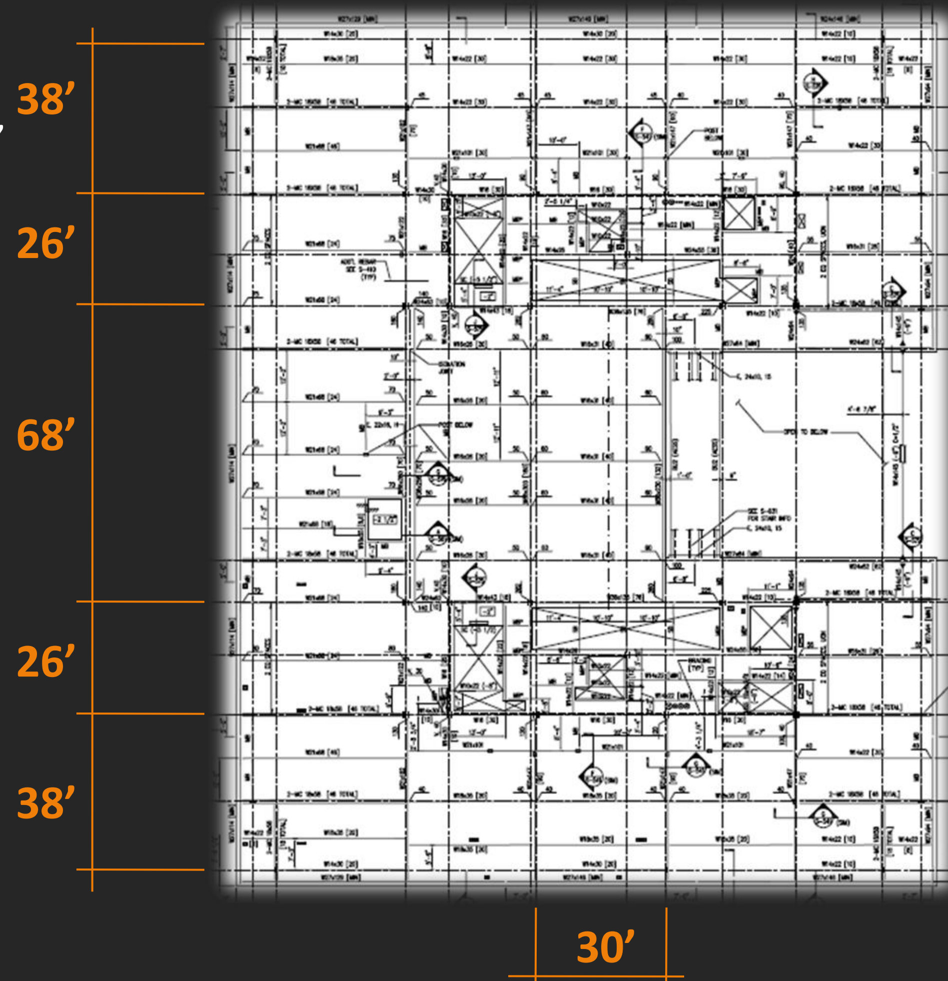
- Reinforced Concrete Piers
  - 20"x20" to 72"x42"
  - Typically extend 10' to individual column footings that bear on bedrock



Existing Structural Systems

Gravity System

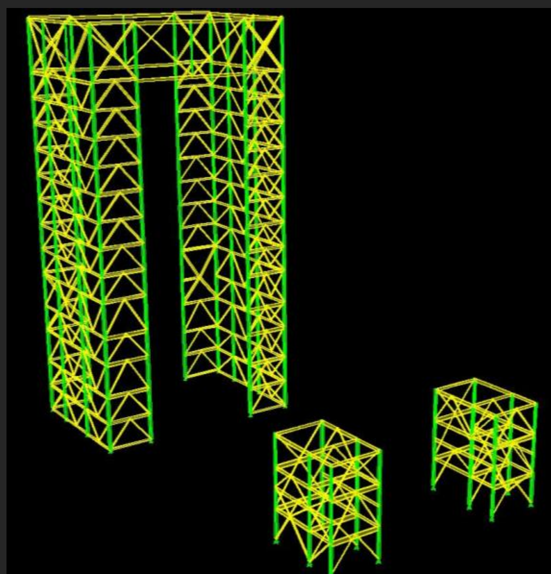
- Composite Steel System
    - 3” metal decking spans 12’
    - 3 ¼” L.W. Concrete
- Typical Floor-to-Floor Height is 15’
- Typical Bay Spacing

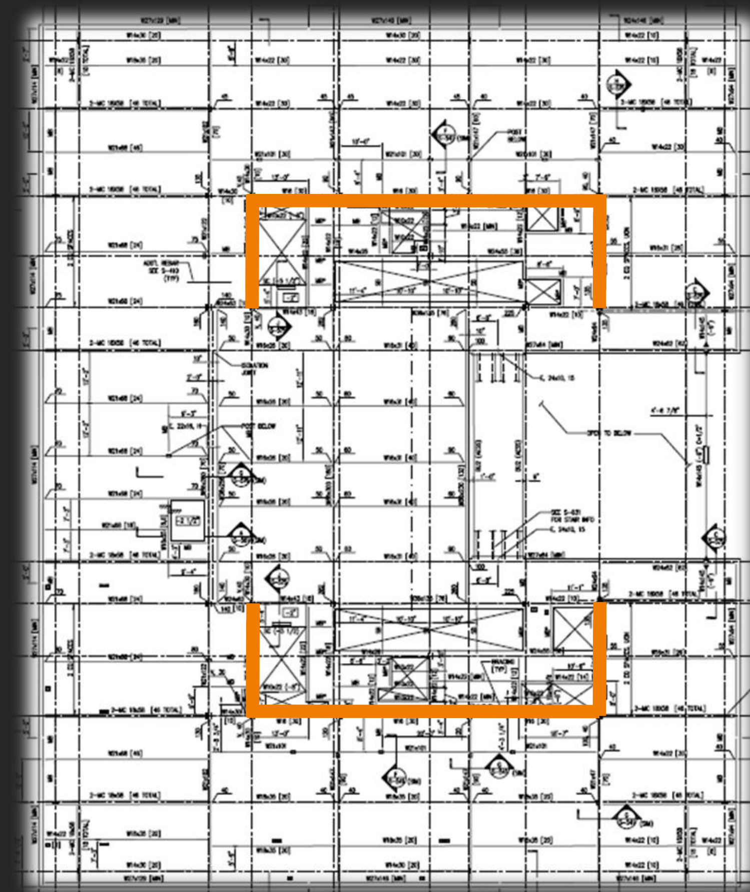


Existing Structural Systems

Lateral Force Resisting System

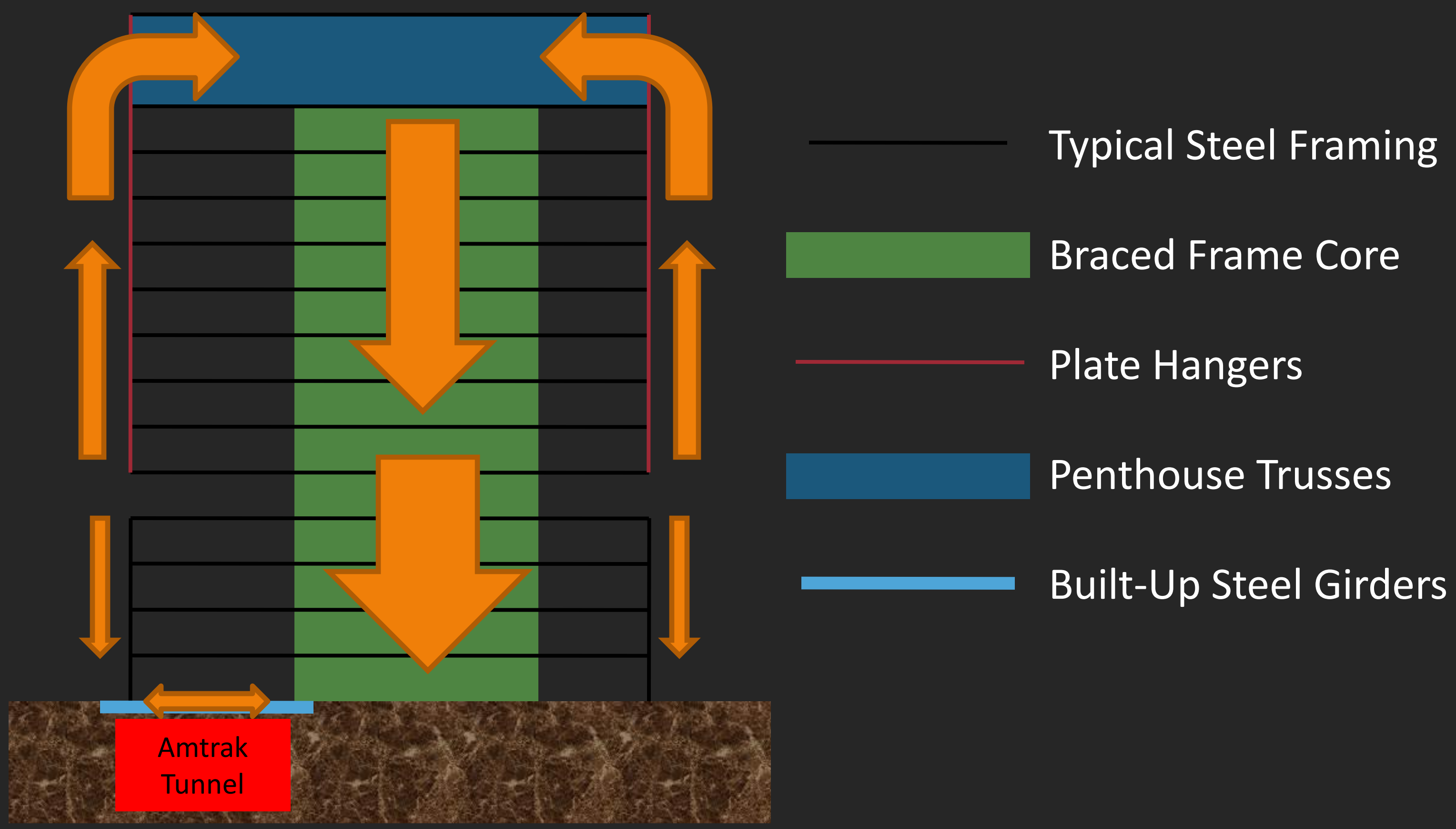
- Concentrically Braced Frame Core
    - Braces range from HSS 6x6x3/8” to HSS 16x8x1/2”





Existing Structural Systems

Transfer System Solution



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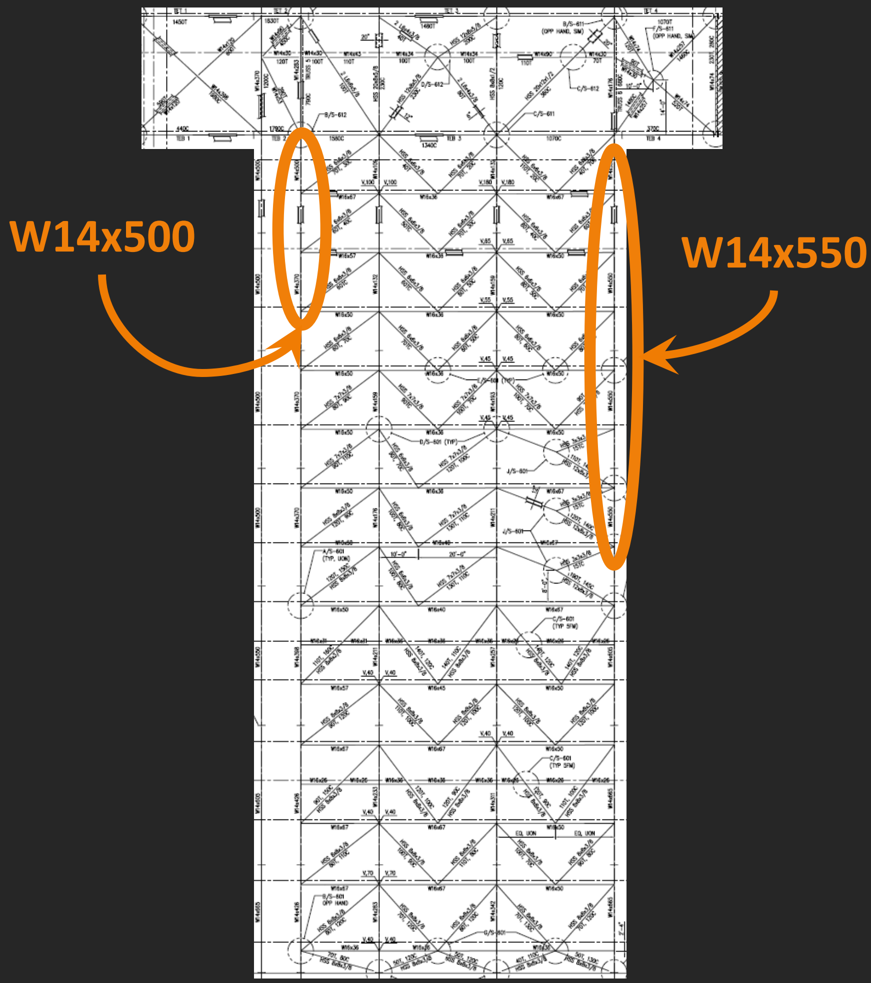
Problem Statement

Inefficient Braced Frames



Difficult Construction Methods

- Use of temporary columns
- Use of stiffened plate hangers to prevent buckling
- Built-up girders above Amtrak tracks must support construction loads of all levels until penthouse trusses are complete
    - Cannot place concrete deck until trusses are complete
- Expensive premiums charged

Problem Solution

Design a New Transfer System

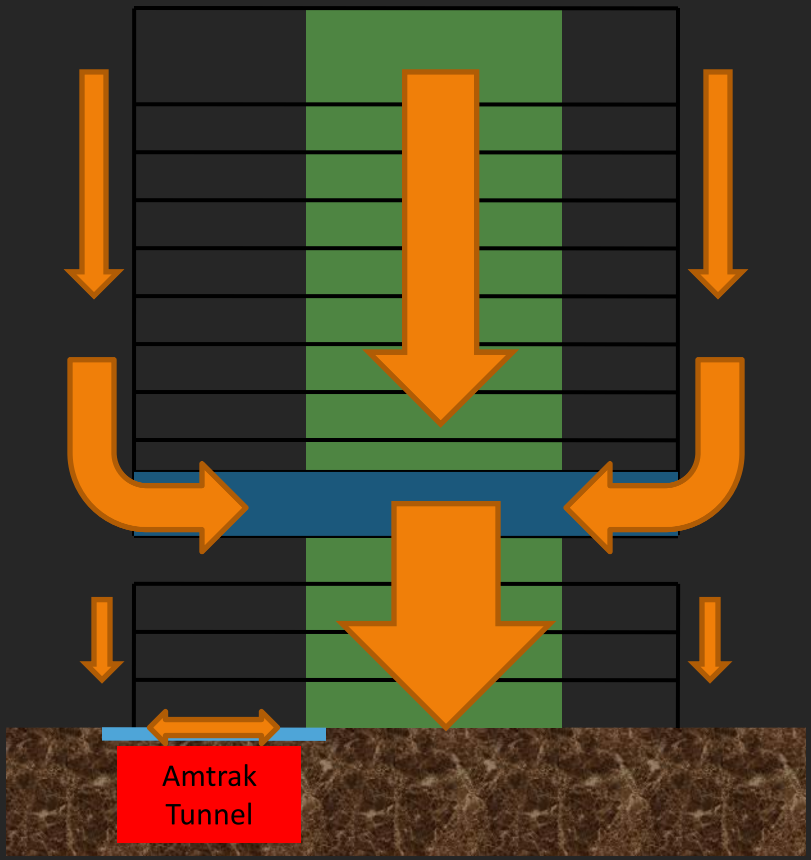
- Optimize the Braced Frame Core
- Allow Traditional Construction Methods
- Gravity Loads are transferred more efficiently
    - All loads transferred down

Typical Steel Framing

Braced Frame Core

Transfer Trusses

Built-Up Steel Girders



Project Goals

- Create a more constructible transfer solution than the existing design

- Design a series of transfer trusses which are architecturally exposed to building occupants

- Design custom built-up steel shapes for exposed truss members

- Perform an in-depth lateral analysis to develop an efficient design for the braced frame core

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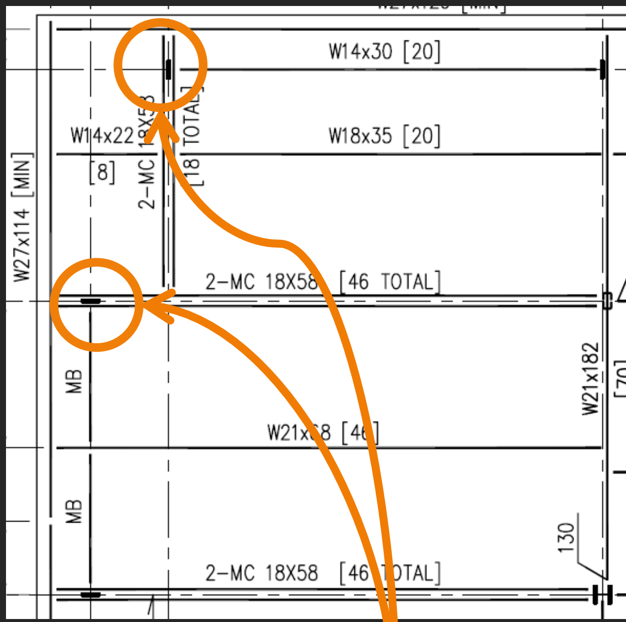
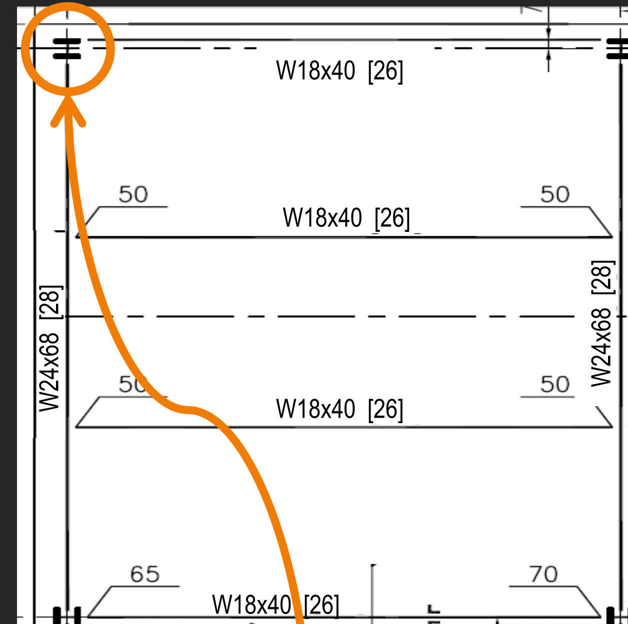
Structural Depth Studies

Corner Column Relocation and Floor Framing Design



Existing Plate Hanger Location

2 Plate Hangers



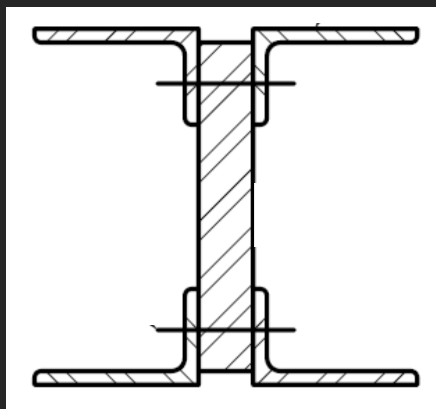
New Column Location

1 Corner Column

Structural Depth Studies

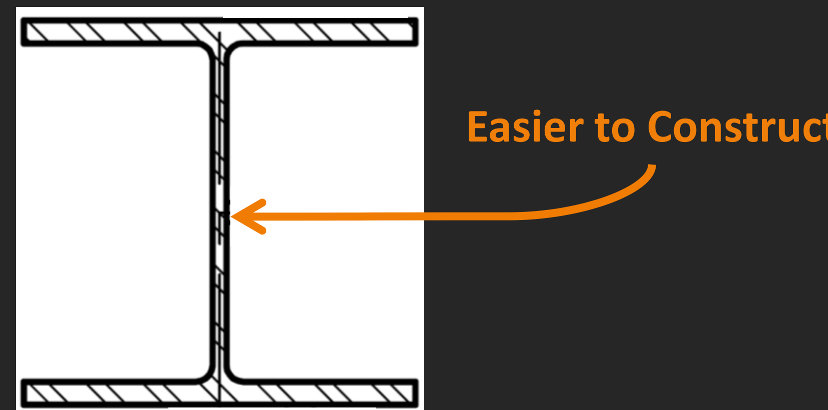
Corner Column Relocation and Design

Existing Plate Hangers



- Total Weight: 107 kips
- Need to reinforce plates during construction to avoid buckling

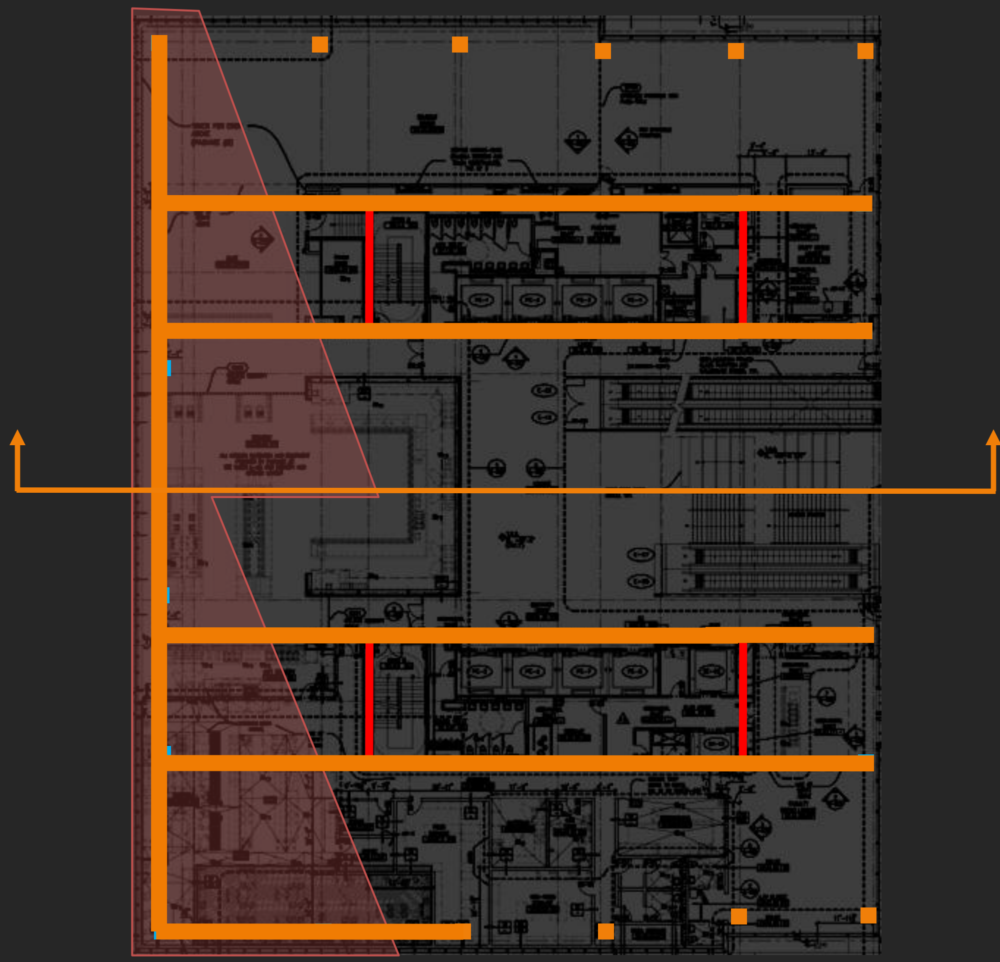
New Columns



- Total Weight: 112 kips
- Typical steel framing can be used

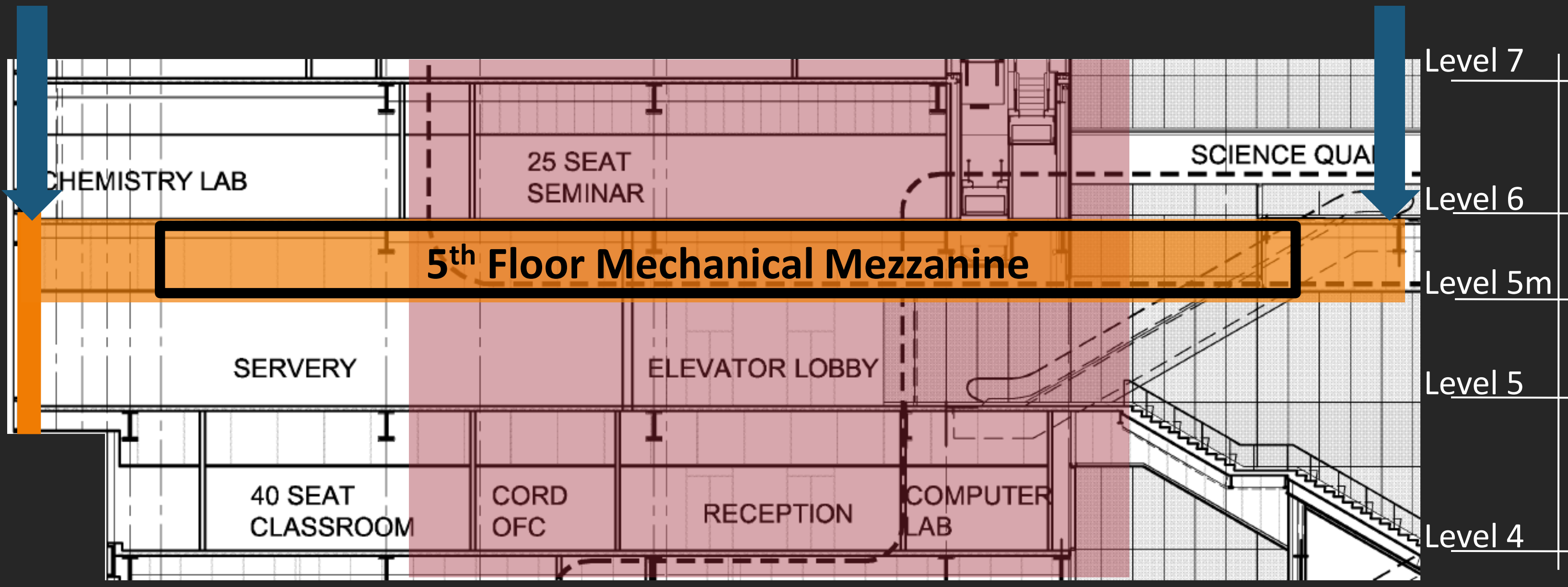
Structural Depth Studies

Transfer Truss Layout



Structural Depth Studies

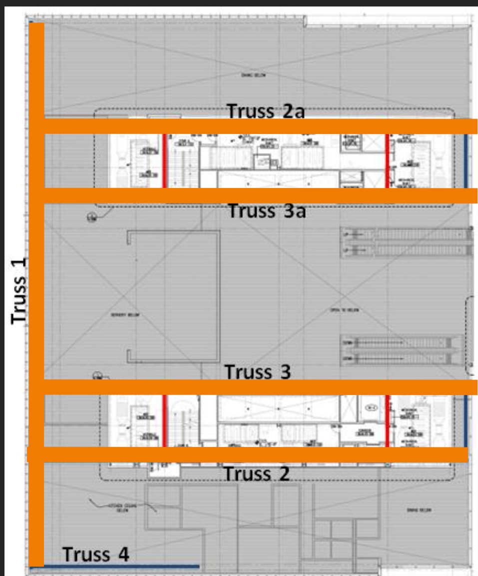
Transfer Truss Layout

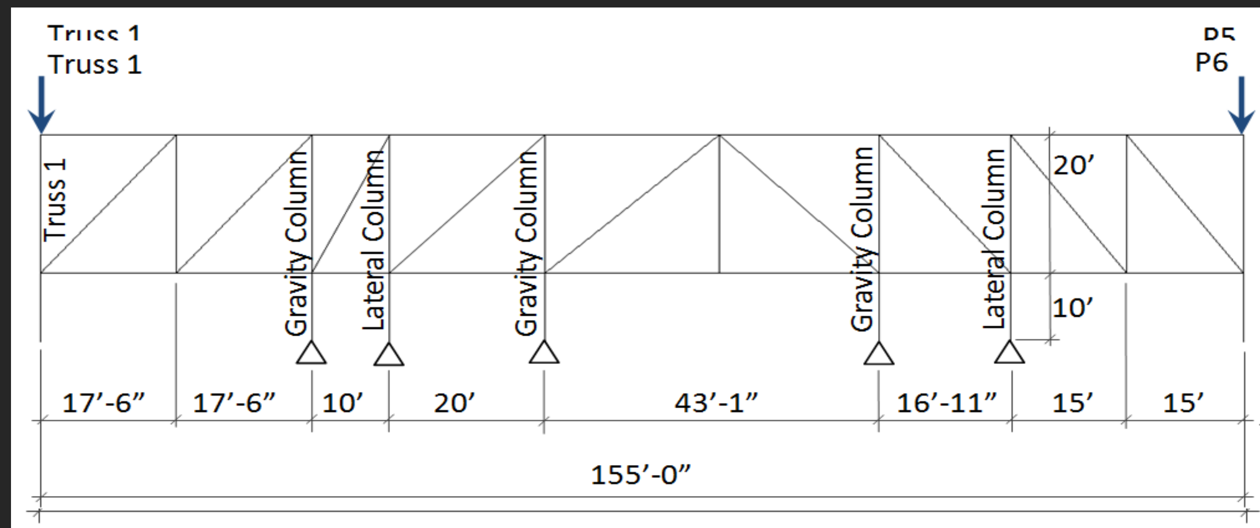


20’ Floor-to-Floor Height

Structural Depth Studies

Transfer Truss Analysis





Truss 2

Loads	P1	P2	P3	P4	P5	P6	P7
Pu (kips)	804	1450	1668	876	1162	1753	1296

Structural Depth Studies

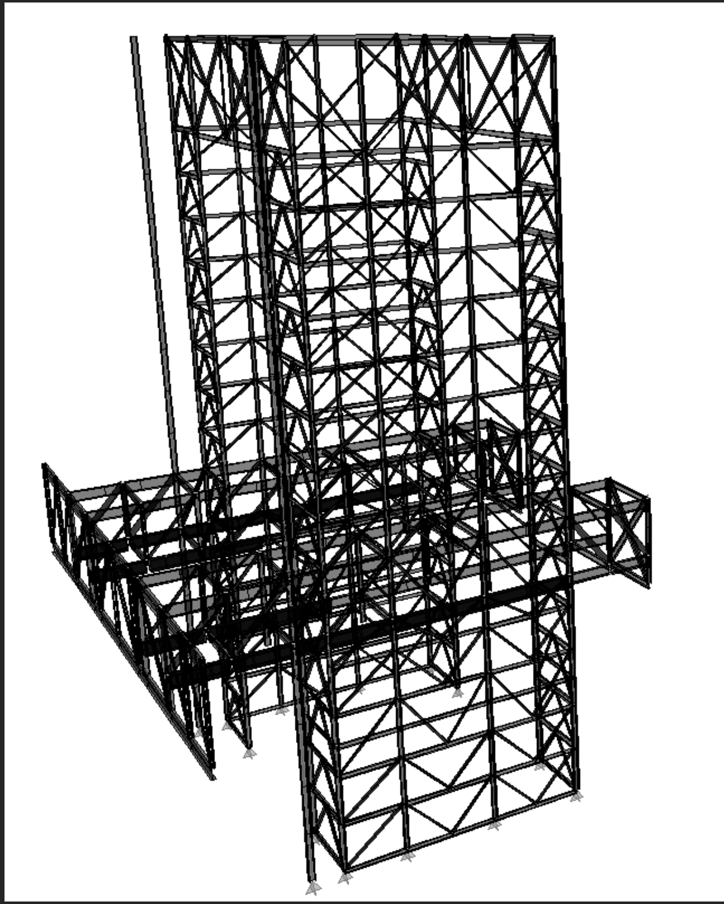
Truss Analysis – ETABS Gravity Model

- Diagonal web members are pinned at each end

- Top and bottom chords are continuous

- Floor diaphragms were not modeled
    - Top and bottom chords resist axial and bending forces
    - Chord unbraced lengths were taken as the distance between vertical web members

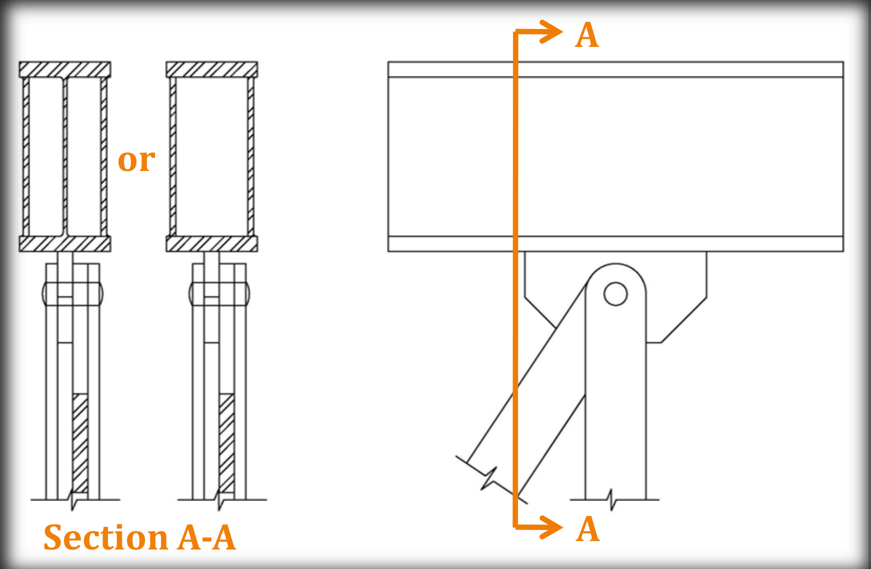
- Gravity Model was also used for deflection calculations



Structural Depth Studies

Truss Member Design

The Newseum "Megatruss"

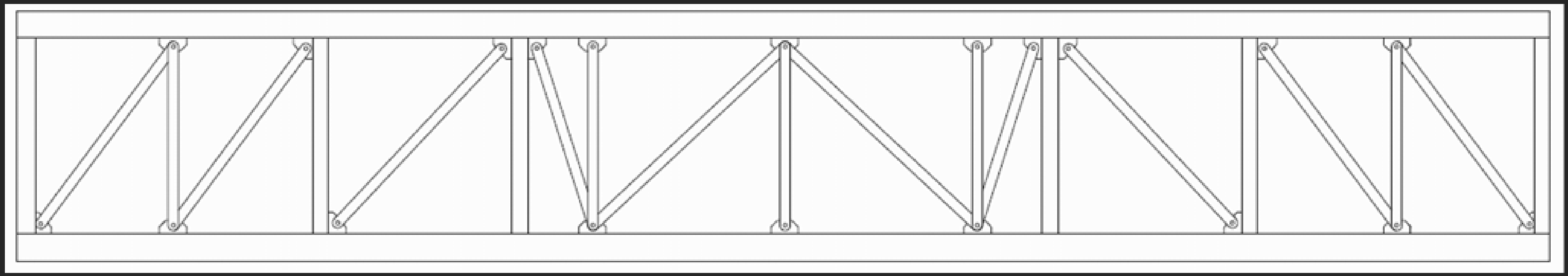


Desired Truss Details

Design of all custom and built-up steel sections comply with the Specification of the 13th Edition AISC Steel Construction Manual

Structural Depth Studies

Truss 1 Final Design



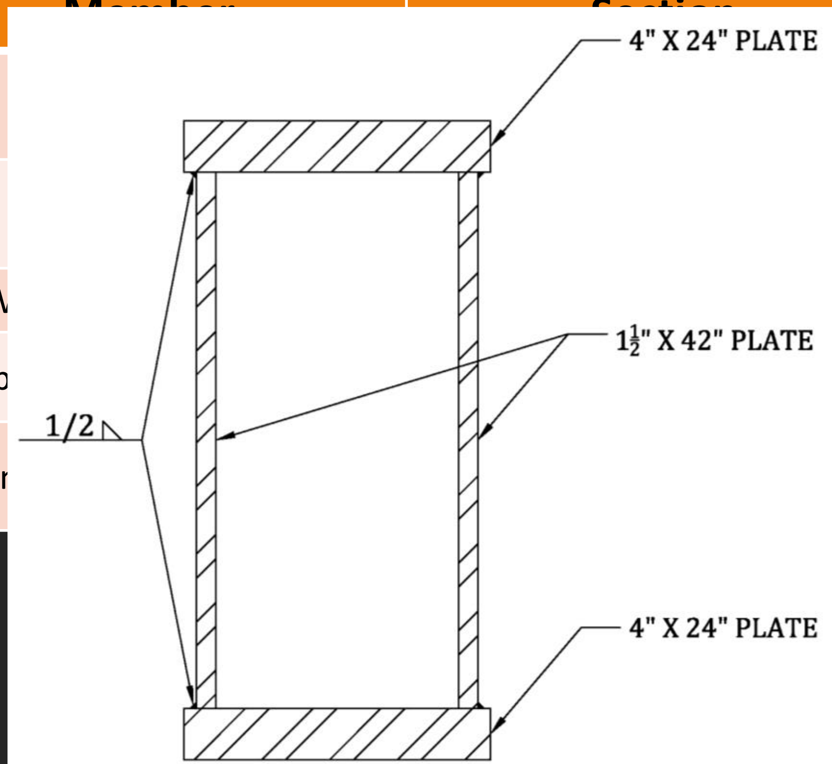
Member	Section	Design Forces
Top and Bottom Chords	W40x362	2700 kips (T) 1960 ft-kips
Web Tension Member	18 x 4 ¼” Plate	2430 kips
Web Compression Member	(2) 16 x 3” Plates stitched at 2’	1960 kips
Common Truss Members	W36x441	3410 kips (C) 680 ft-kips

Structural Depth Studies

Truss 2 Final Design

Member	Section	Design Forces
		5800 kips (T) 4500 ft-kips
		6000 kips (C) 9500 ft-kips
W		4850 kips
Web	t 1’	3370 kips
Cor		3410 kips (C) 680 ft-kips

- 4” thick flanges
- 1 ½” thick web
- 50” deep x 24” wide
- Weighs 1082 PLF



Structural Depth Studies

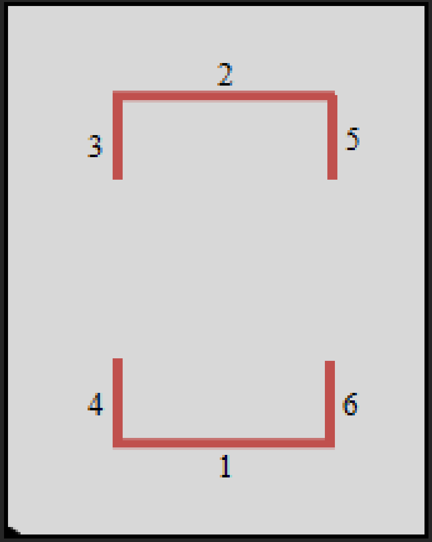
Transfer Truss Comparison

Criteria	Thesis Transfer System	Existing Transfer System
Number of Transfer Trusses	6	10
Perimeter Columns Transferred	11/20 (55%)	24/24 (100%)
Total Web Members	102	206
Avg. Truss Weight (kips)	230	152
Interior Truss Height	20'-0"	30'-0"
Number of Levels Being Transferred w/ Trusses	11	10

Structural Depth Studies

Lateral Analysis and Design

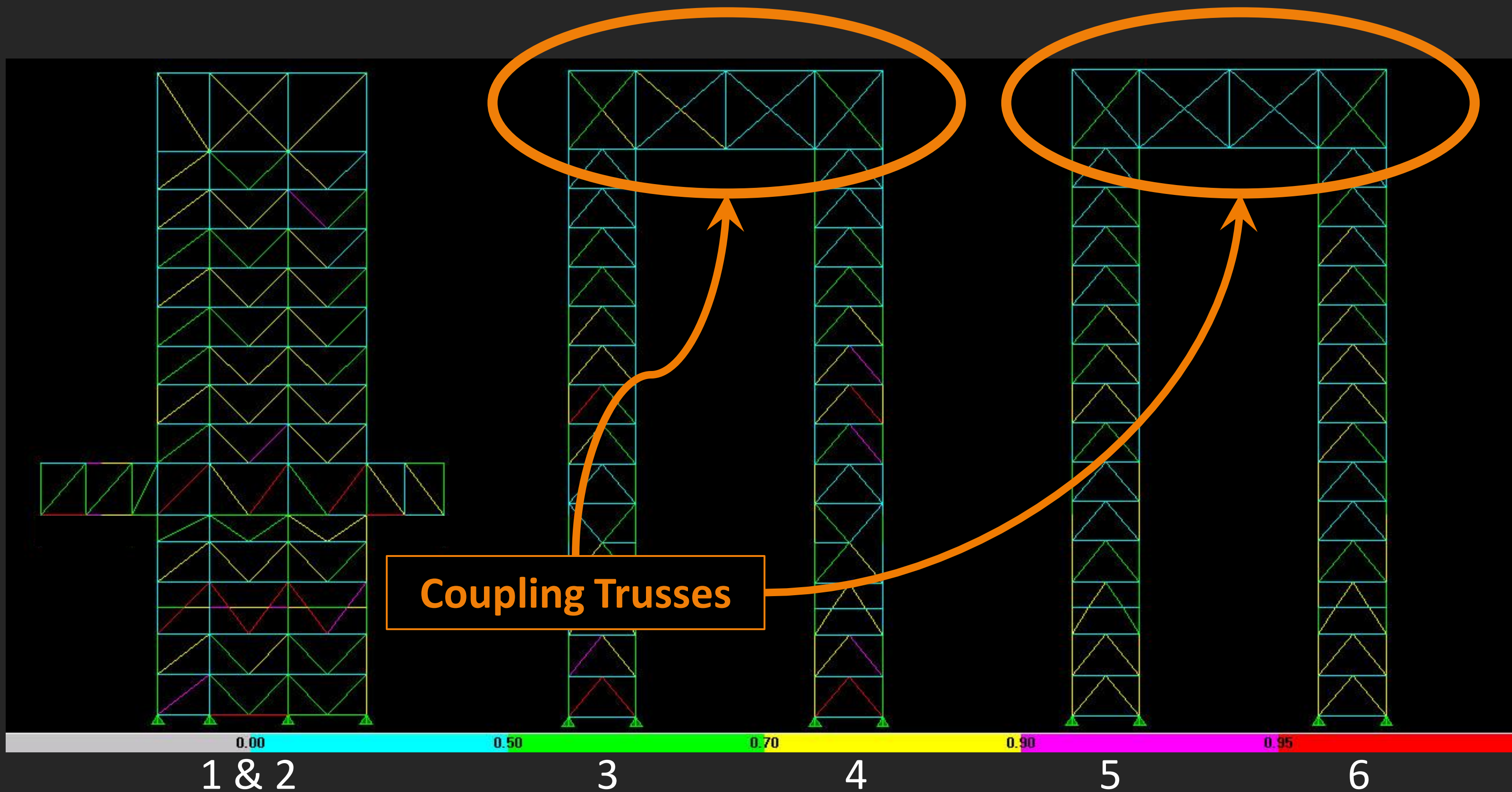
- Tower Braced Frame Core Re-design
- ETABS Lateral Model
  - Floors modeled as rigid diaphragms
  - Lateral loads distributed based on relative stiffness of each braced frame
- Lateral loads determined using ASCE 7-05
  - Wind: Method 2 of Chapter 6
  - Seismic: ELFP of Chapter 11 (SDC: B)
  - Wind governed for strength and serviceability



Structural Depth Studies

Lateral Analysis and Design

Braced Frame Configurations and Demand-to-Capacity Ratios



Structural Depth Studies

Lateral Analysis and Design – Braced Frame 1 & 2

Existing Typical Members

Level	Column	Brace	Girder
1 - 3	W14x665	HSS 8x8x3/8	W16x67
4-7	W14x605	HSS 8x8x3/8	W16x45
7-10	W14x550	HSS 7x7x3/8	W16x36
11-14	W14x550	HSS 6x6x3/8	W16x36

Largest Brace is an HSS 8x8x3/8

Re-designed Typical Members

Level	Column	Brace	Girder
1 - 3	W14x455	HSS 8x8x3/8	W16x67
4-7	W14x455	HSS 8x8x5/8	W16x45
7-10	W14x176	HSS 8x8x3/8	W16x36
11-14	W14x99	HSS 6x6x3/8	W16x36

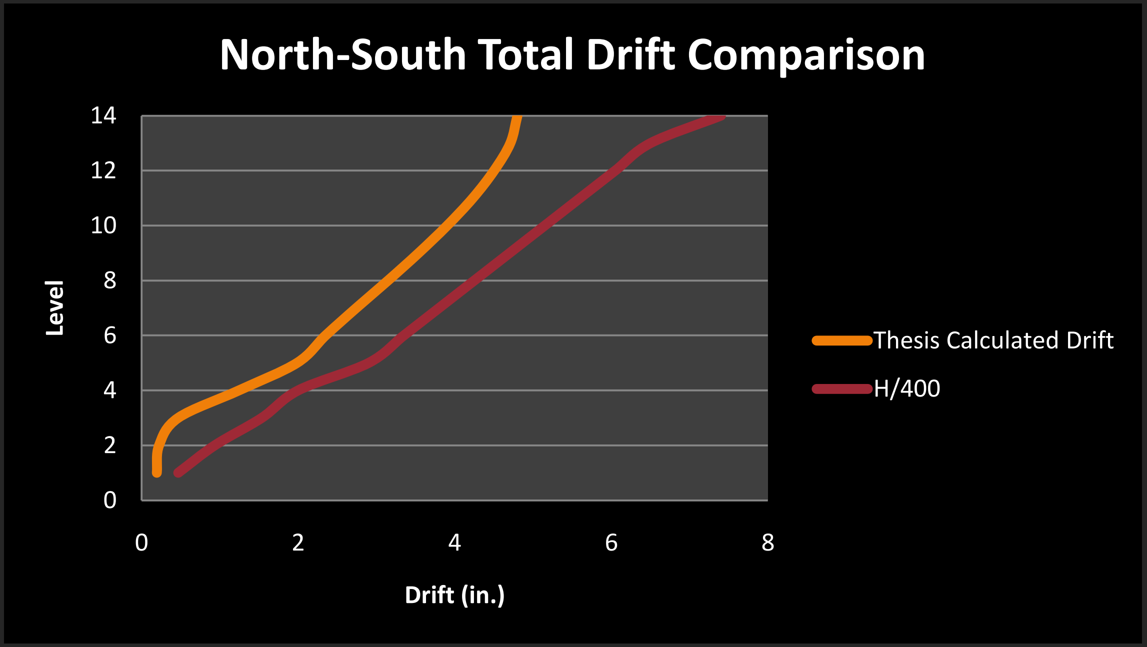
Largest Brace is an HSS 20x12x5/8

New braced frame design resulted in saving
71 tons of steel in columns

Structural Depth Studies

Lateral Drift – ASCE 7-05

- Calculated Lateral Drifts
  - Wind:
    LC: 0.7W (App. C)
  - Seismic:
    $\delta_{xe}\ C_d\ /\ I$



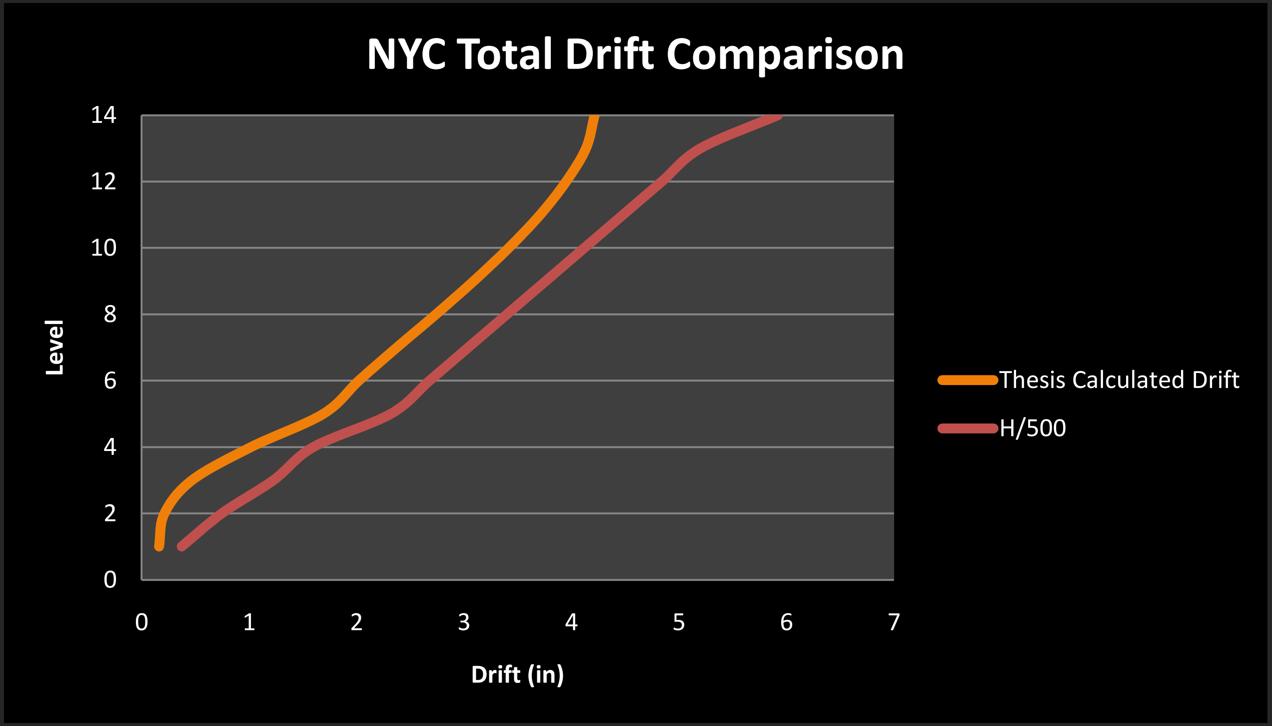
- Lateral Drift Limitations
  - Wind:
    H/400
  - Seismic:
    $0.015h_{sx}$

- Lateral Drifts due to wind governed
  - Maximum drift is in N-S direction

Structural Depth Studies

Lateral Drift – New York City Building Code

• Necessary to compare re-design to the original design criteria



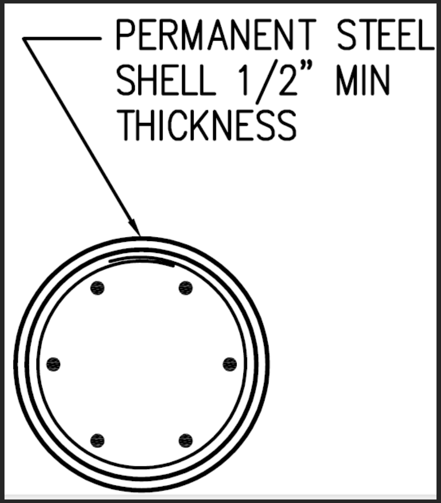
Structural Depth Studies

Foundation Impacts

• Perimeter columns not transferred using 5th level trusses now extend to the foundation

• Existing concrete caissons support 5 levels of gravity load, where the new design calls for 14 levels of gravity loads

	Existing	Thesis
Diameter	18"	36"
Reinforcement	(7) #14 Bars	(11) #14 Bars



Impacts are minimal as only 7 caissons need changed

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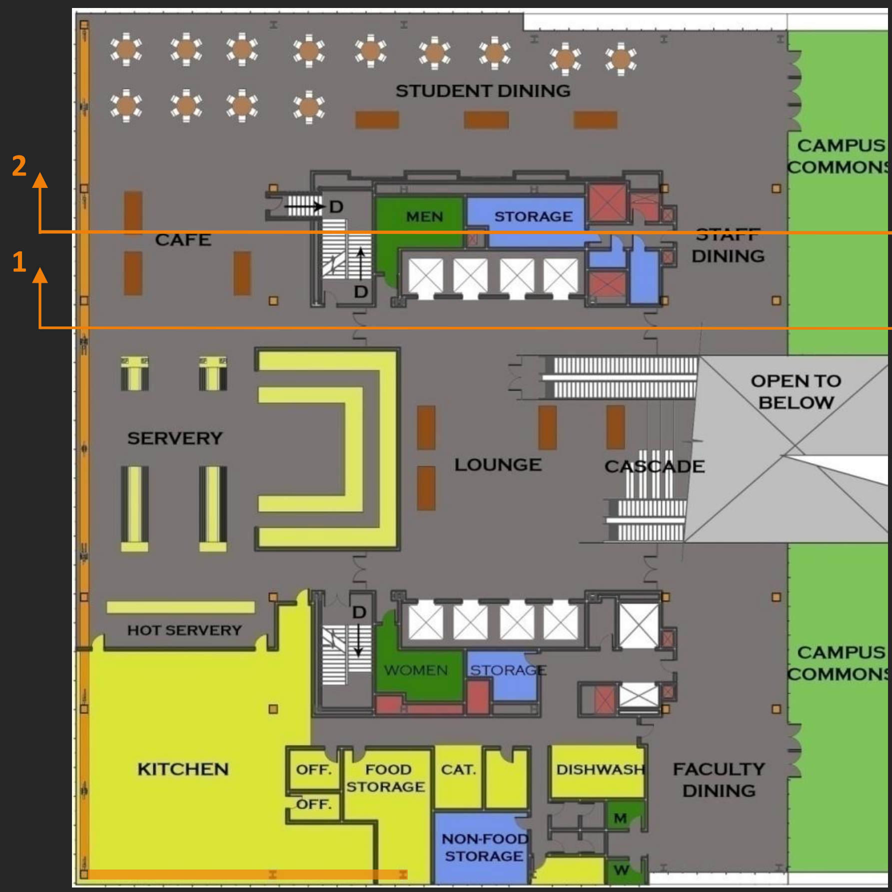
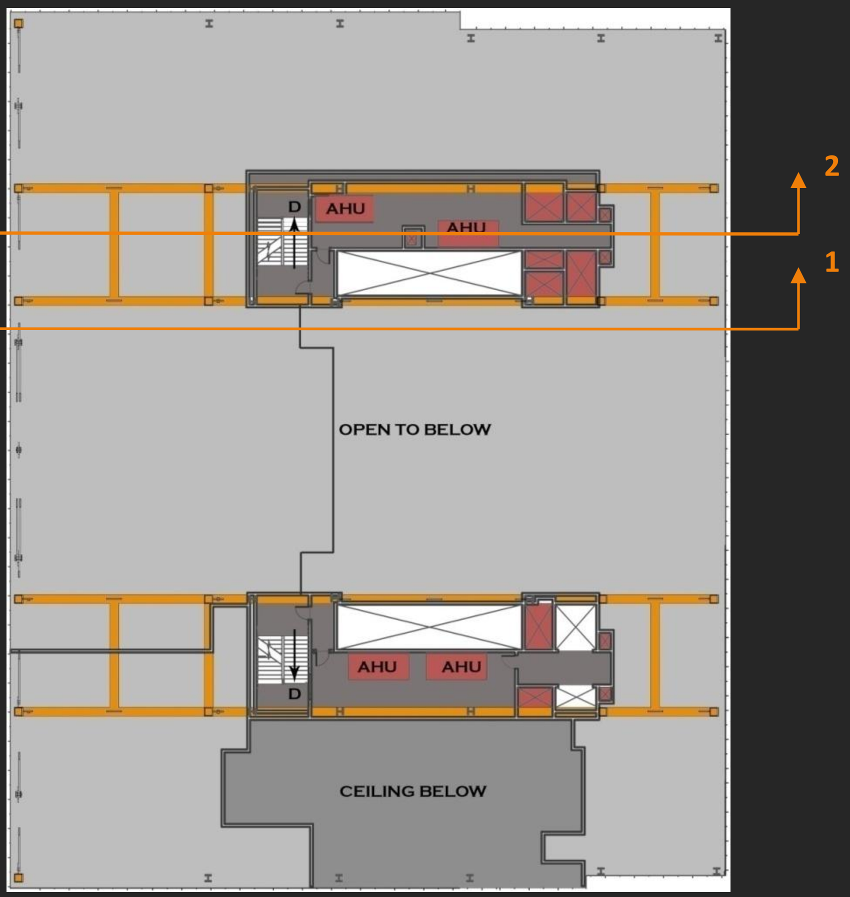
Architectural Breadth Studies

5th Level Floor Plan

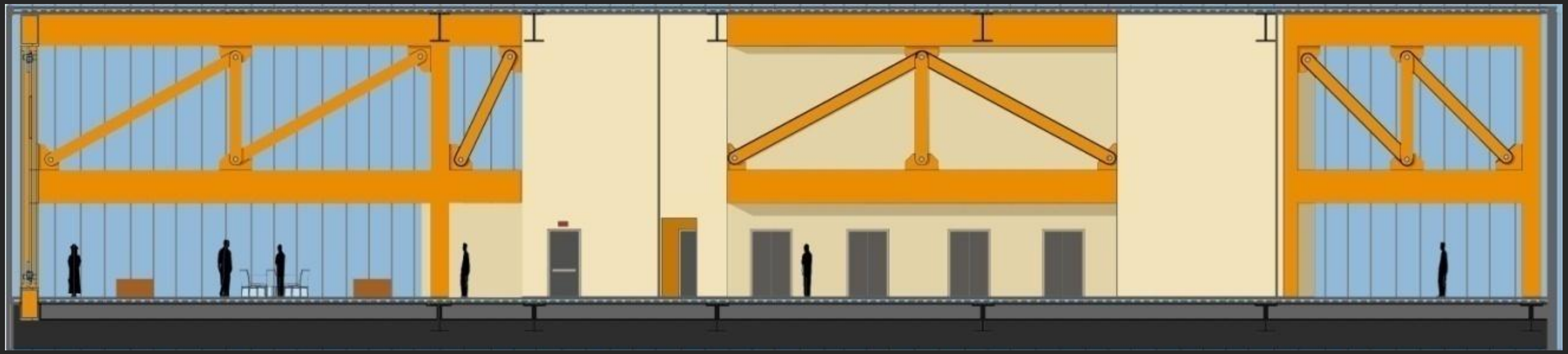


5th Level Mezzanine Floor Plan

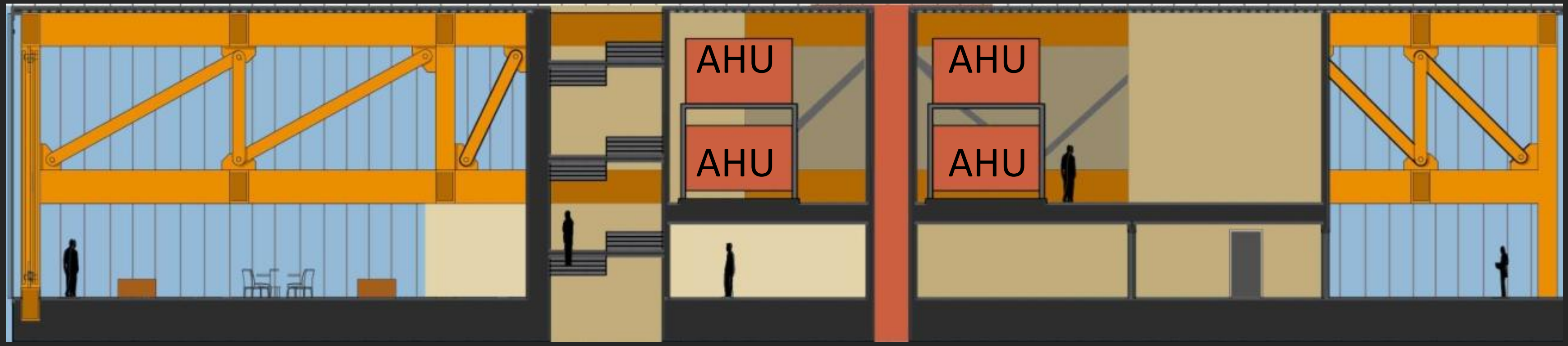


Architectural Breadth Studies

Section 1



Section 2



Architectural Breadth Studies

Interior Renderings

Architectural Breadth Studies

Existing Exterior Renderings

Architectural Breadth Studies

New Exterior Renderings

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Construction Management Breadth Studies

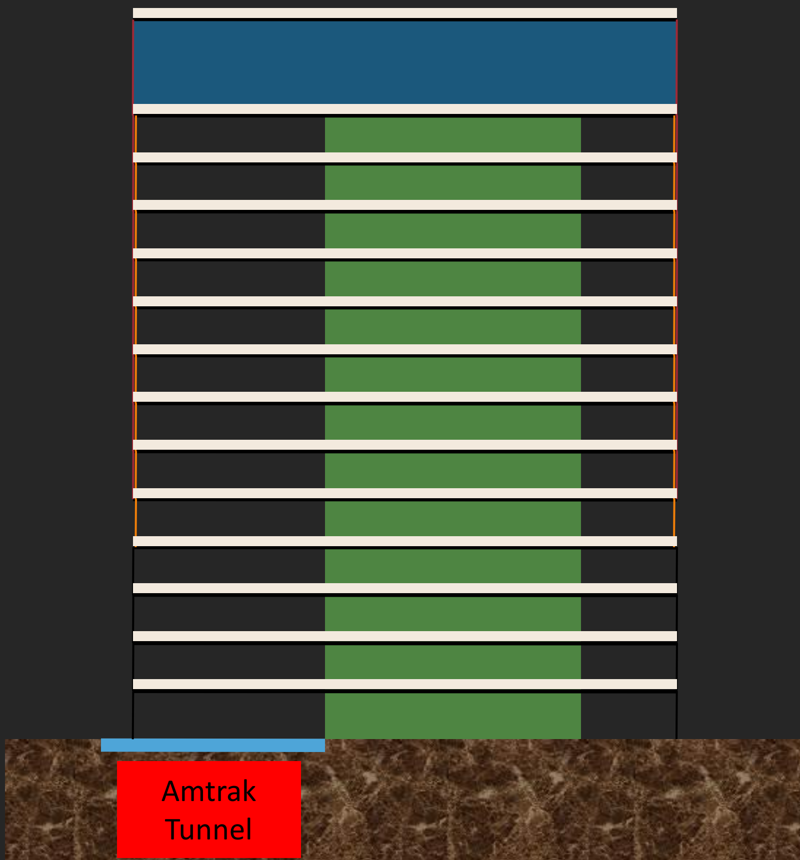
Cost Comparison

	Thesis (kips)	Existing (kips)
Cost of Steel	$ 5.83 Million	$ 6.24 Million
Increased Curtain Wall Cost	$ .820 Million	--
Preconstruction Costs	$ 0.069 Million	$ 0.114 Million
Dismantle Temporary Supports	--	$ 0.125 Million
Hydraulic Jacks	--	$ 0.125 Million
Total	**$ 6.71 Million**	**$ 6.60 Million**

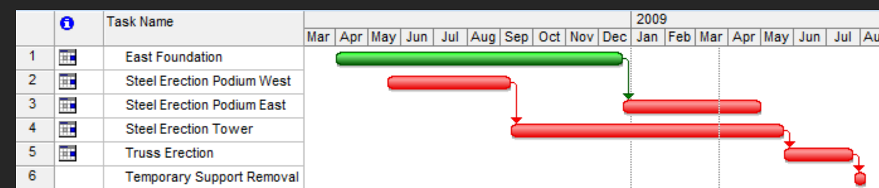
Both systems cost about the same

Construction Management Breadth Studies

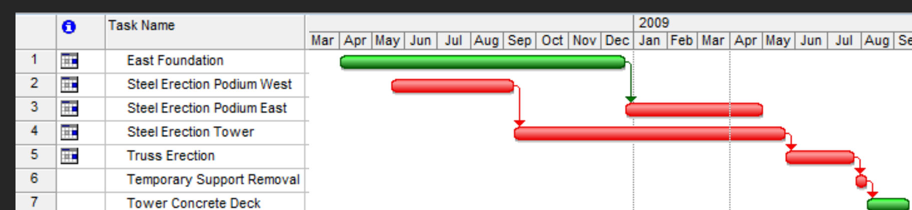
Schedule Comparison – Existing Sequence



Steel Erection Time: 63 Weeks

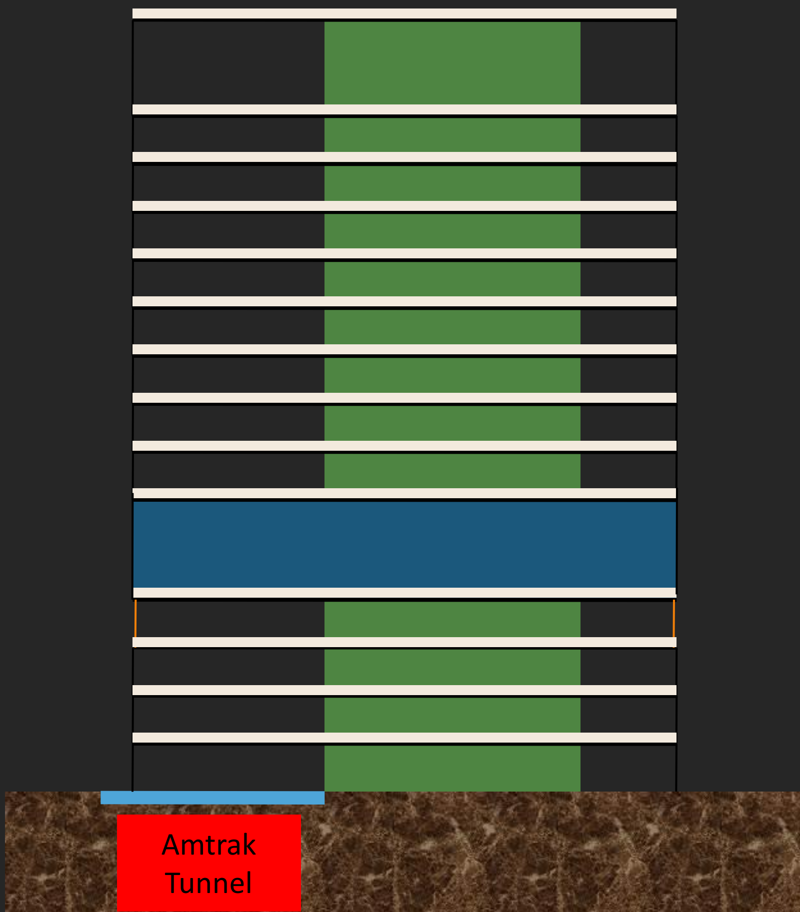


Total Superstructure Time: 70 Weeks

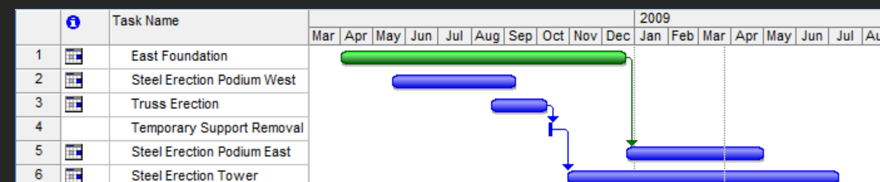


Construction Management Breadth Studies

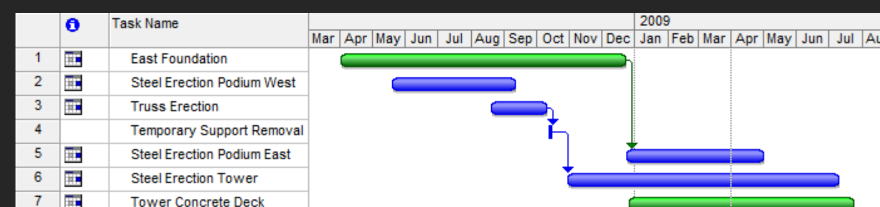
Schedule Comparison – New Sequence



Steel Erection Time: 60 Weeks



Total Superstructure Time: 64 Weeks



Construction Management Breadth Studies

Construction Conclusions

	Thesis Transfer System	Existing Transfer System
Structural System Cost	$ 5.89 Million	$ 6.60 Million
Total Cost	$ 6.71 Million	$ 6.60 Million
Steel Erection Schedule (Weeks)	60	63
Entire Superstructure Schedule (Weeks)	64	70

- Steel erection tops out 3 weeks earlier using the new transfer system
- Total superstructure schedule is 6 weeks less using the new transfer system

- **Less trusses and truss members**
- **Eliminating the use of temporary supports in tower construction**
- **Using typical steel framing**

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Conclusions and Recommendation

- Braced Frame Core was optimized by relocating the transfer trusses to the 5th level

- Exposed steel transfer trusses with custom steel members compliment the 5th level dining commons

- A more constructible structure was achieved

Recommendation:

Use the new transfer solution

Acknowledgements

A special thanks to:

Jason Stone, PE
Patrick Hopple

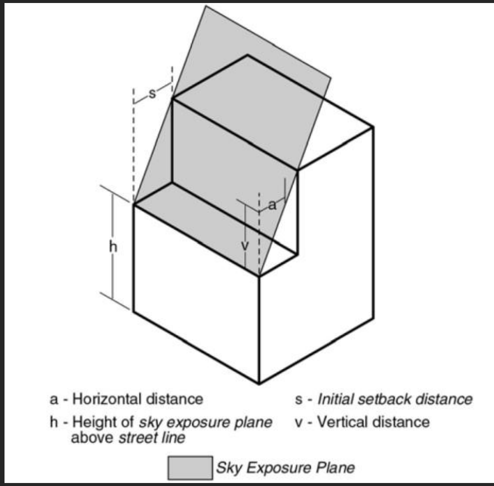
Anthony Gervaise, LEED AP

Ramesh Rastogi

I also would like to thank my friends and family for their support over the past year, this project would not have been possible without you.

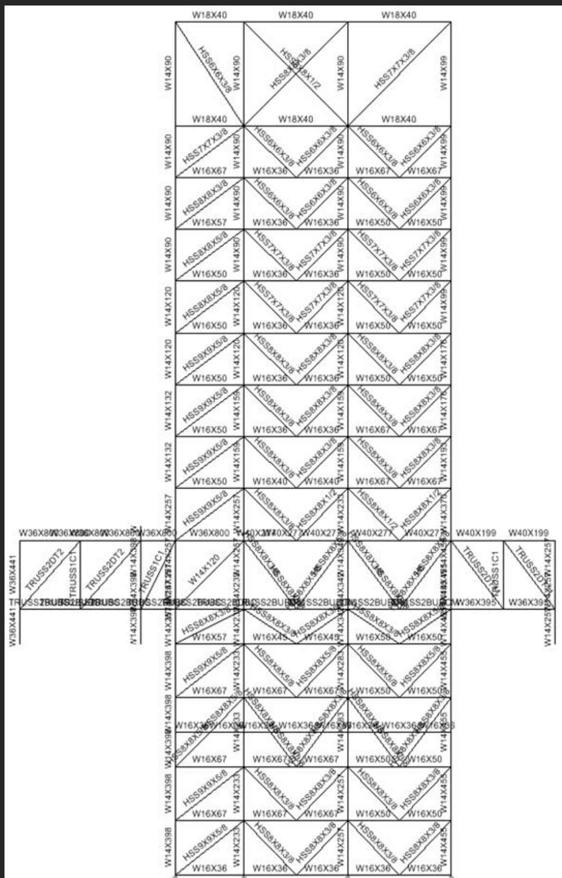
Questions?

Building Height Limitations

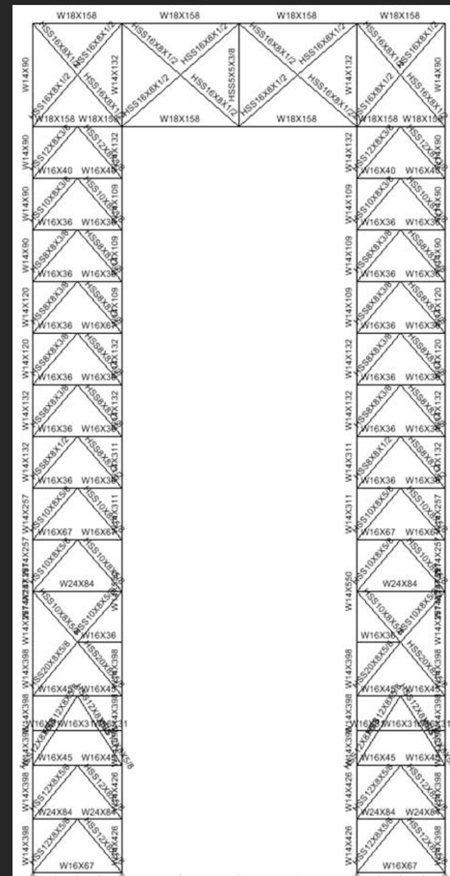


- C6-2 Special Purpose Zone – **No Maximum Building Height**
- However, NYC has building setback requirements
- Sky Exposure Plane
    - For a C6-2 Zone, vertical to horizontal ratio is 7.6 : 1
    - Existing design requires a setback of 20’ at the roof and only 15’ is provided
    - Assumed that a variance was obtained or the zone was changed

Braced Frames



1 & 2



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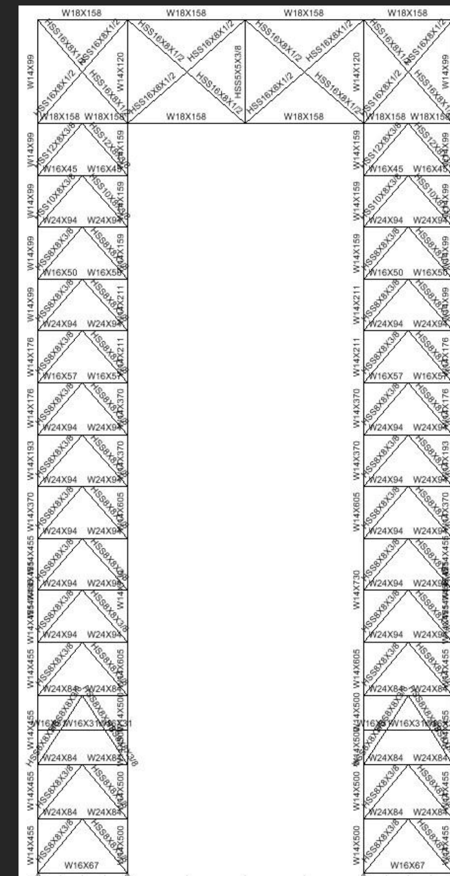

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Load Combinations

ASCE 7 – 05 Load Combinations

1. $1.4D$
2. $1.2D + 1.6L + 0.5L_r$ ← Transfer System Members
3. $1.2D + 1.6L_r + (L \text{ or } 0.8W)$
4. $1.2D + 1.6W + L + 0.5L_r$ ← Braced Frame Members
5. $(1.2 + 0.2S_{DS})D + E + L$
6. $0.9D + 1.6W$
7. $(0.9 - 0.2S_{DS})D + E$

Scheduling Assumptions

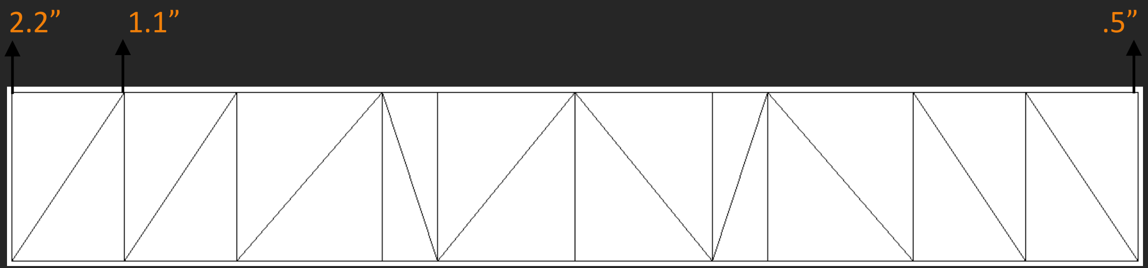
Activity	Thesis (Duration in Days/Level)	Existing (Duration in Days/Level)
Erect Columns	1	1
Erect Braced Frames	1	1
Erect Typical Floor Framing	7	7
Decking and Detailing	10	10
Erect Temporary Columns	1	1
Erect Reinforced Plate Hangers	N/A	1
Erect Truss Bottom Chords	3	4
Erect Truss Top Chords	2	4
Erect Truss Web Members	3	6
Detail and Plum Trusses	5	10
Remove Temporary Columns/Reinforced Plates	1[1]	5[1]
Placing Concrete Decking	10[2]	2[3]

[1] - Unit is Total Days

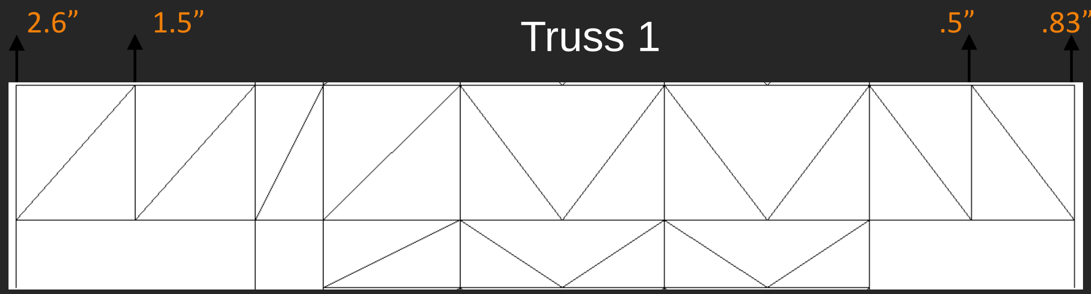
[2] – Includes duration of embeds, box outs, rebar, and placing concrete

[3] – Includes placing concrete

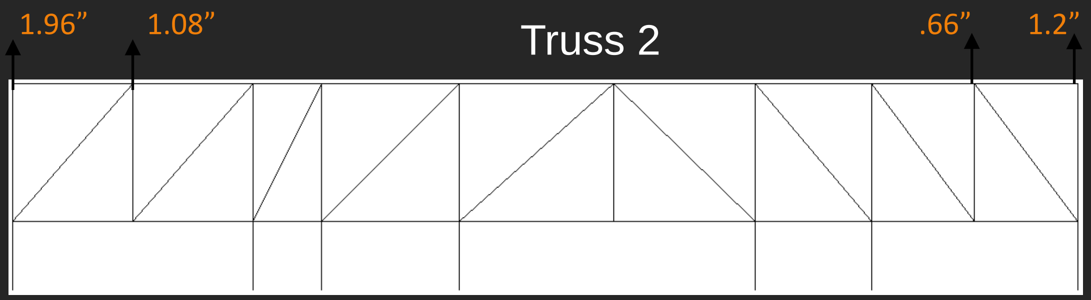
Truss Cambers and Deflections



Truss 1



Truss 2



Truss 3

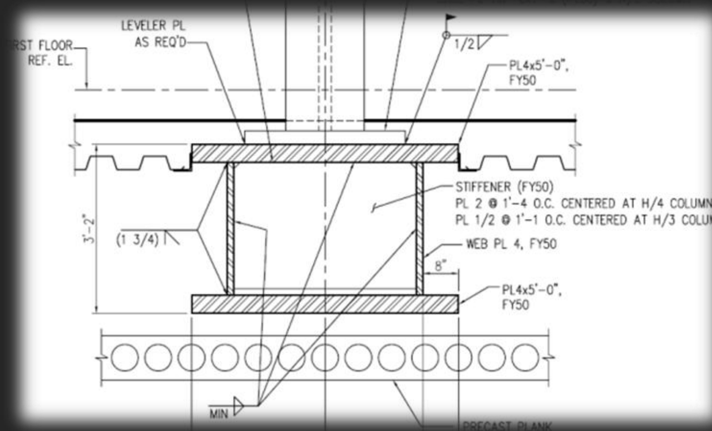
Maximum Live Load Deflections

Truss	L (ft)	$0.5\Delta_L$ (in)	(L/250) (in)
1	40	1.41	1.92
2	35	0.73	1.68
2a	35	0.35	1.68
3	35	0.53	1.68
3a	35	0.36	1.68

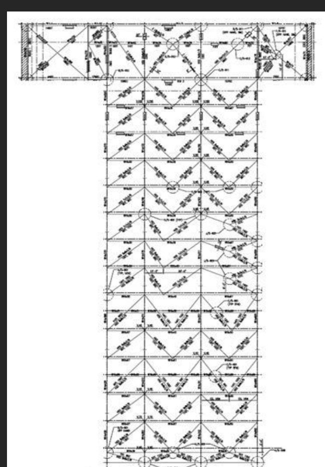
Existing Structural Systems

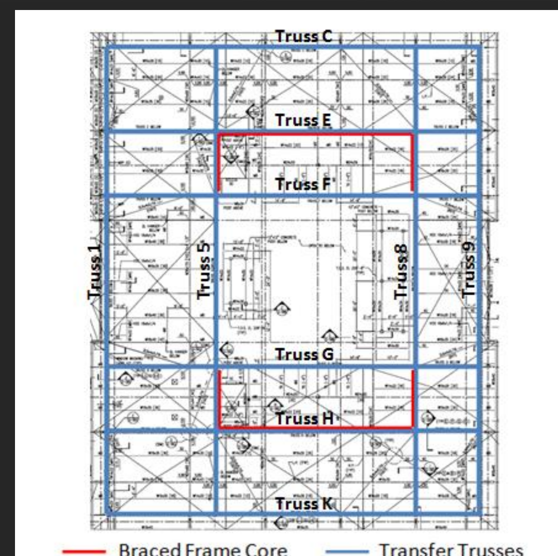
Transfer System Solution

- Floors 1 – 5 transferred using built-up girders



- Floors 6 – Roof are hanging and are transferred at the penthouse level using trusses

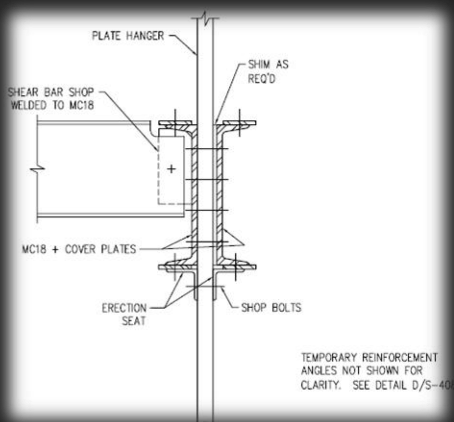


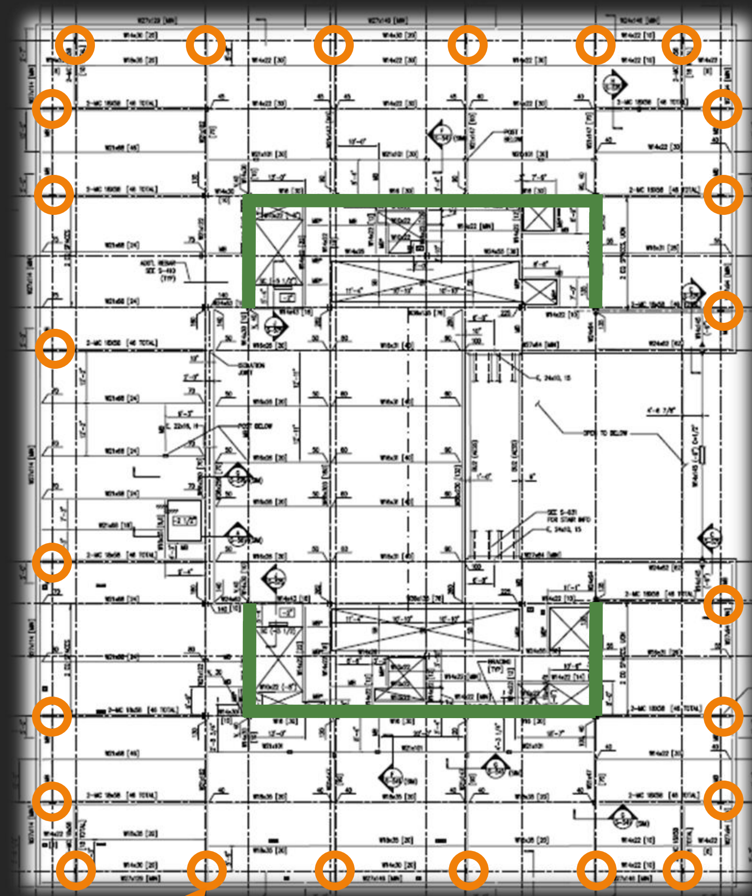


Existing Structural Systems

Transfer System Solution

- Floors 6 – Penthouse use perimeter plate hangers instead of columns

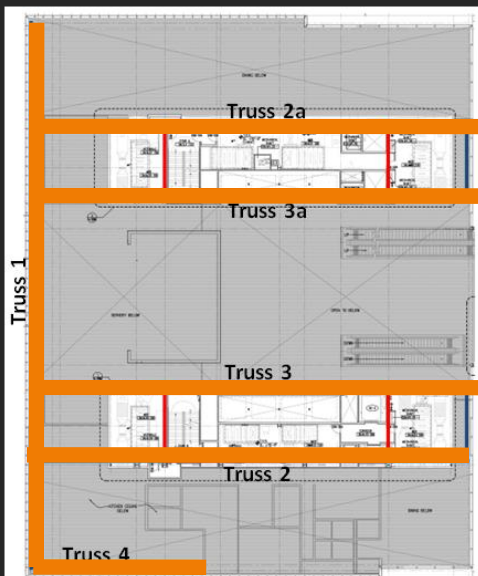


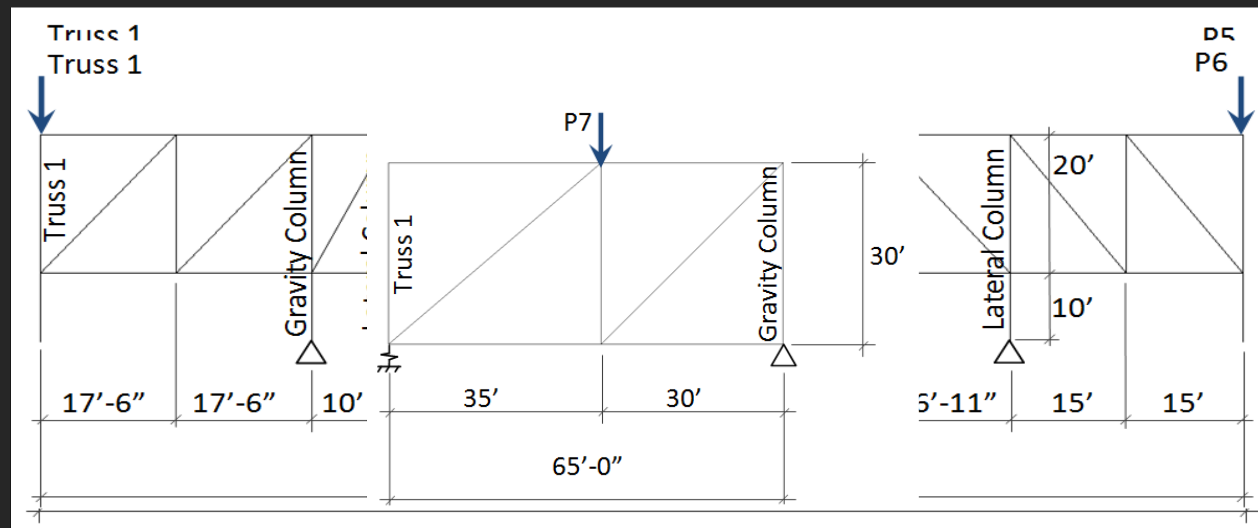


Perimeter Plate Hangers

Structural Depth Studies

Transfer Truss Analysis





Truss 4

Loads	P1	P2	P3	P4	P5	P6	P7
Pu (kips)	804	1450	1668	876	1162	1753	1296

Structural Depth Studies

Lateral Analysis and Design

Existing Braced Frame 3 & 4

Level	Column	Brace	Girder
1 - 3	W14x426	HSS 8x8x3/8	W24x84
4-7	W14x398	HSS 20x8x1/2	W16x67
7-10	W14x370	HSS 8x8x3/8	W16x36
11-14	W14x500	HSS 16x8x1/2	W16x36

Re-designed Braced Frame 3 & 4

Level	Column	Brace	Girder
1 - 3	W14x426	HSS 12x8x5/8	W24x84
4-7	W14x550	HSS 20x8x5/8	W16x67
7-10	W14x132	HSS 8x8x1/2	W16x36
11-14	W14x132	HSS 12x8x3/8	W16x36

Structural Depth Studies

Lateral Analysis and Design

Existing Braced Frame 5 & 6

Level	Column	Brace	Girder
1 - 3	W14x665	HSS 8x8x3/8	W24x84
4-7	W14x605	HSS 10x8x3/8	W24x94
7-10	W14x455	HSS 10x8x3/8	W24x94
11-14	W14x342	HSS 16x8x1/2	W24x94

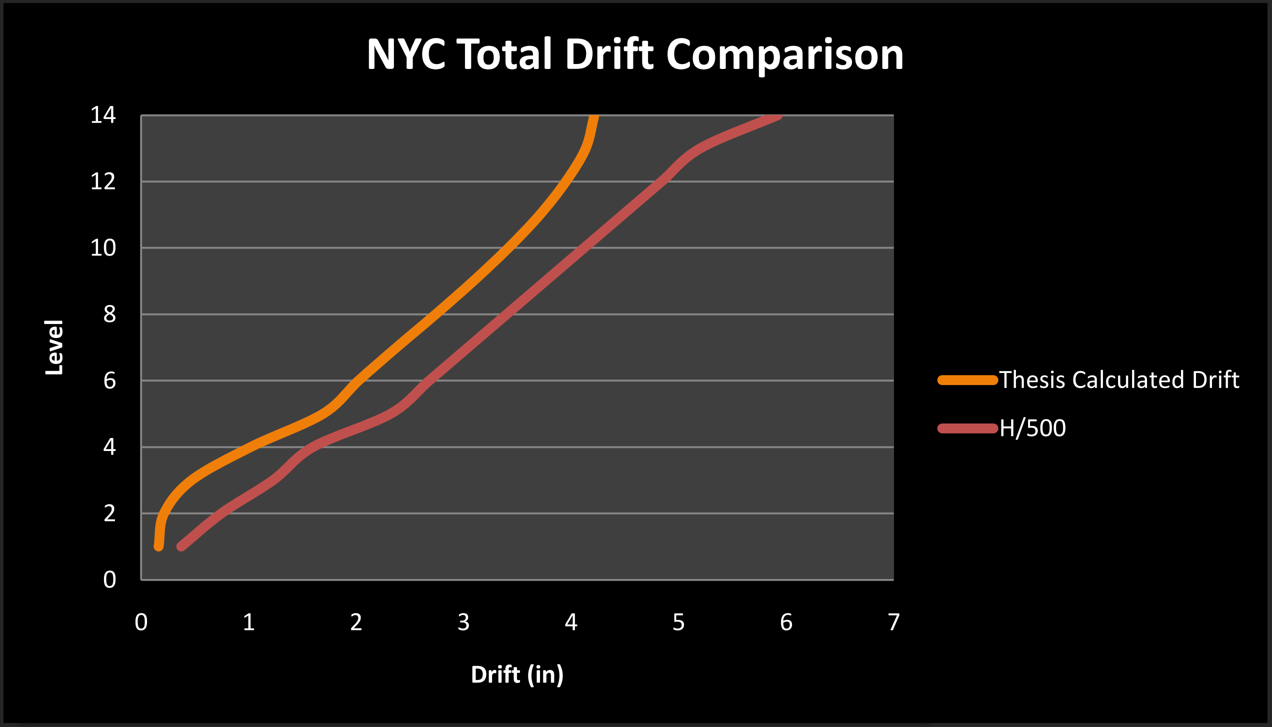
Re-designed Braced Frame 5 & 6

Level	Column	Brace	Girder
1 - 3	W14x500	HSS 8x8x3/8	W24x84
4-7	W14x730	HSS 8x8x3/8	W24x94
7-10	W14x370	HSS 8x8x3/8	W24x94
11-14	W14x159	HSS 12x8x3/8	W24x94

Structural Depth Studies

Lateral Drift – New York City Building Code

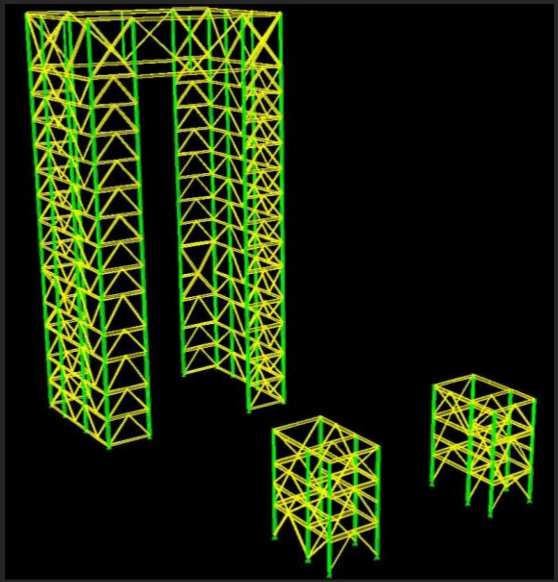
• Necessary to compare re-design to the original design criteria

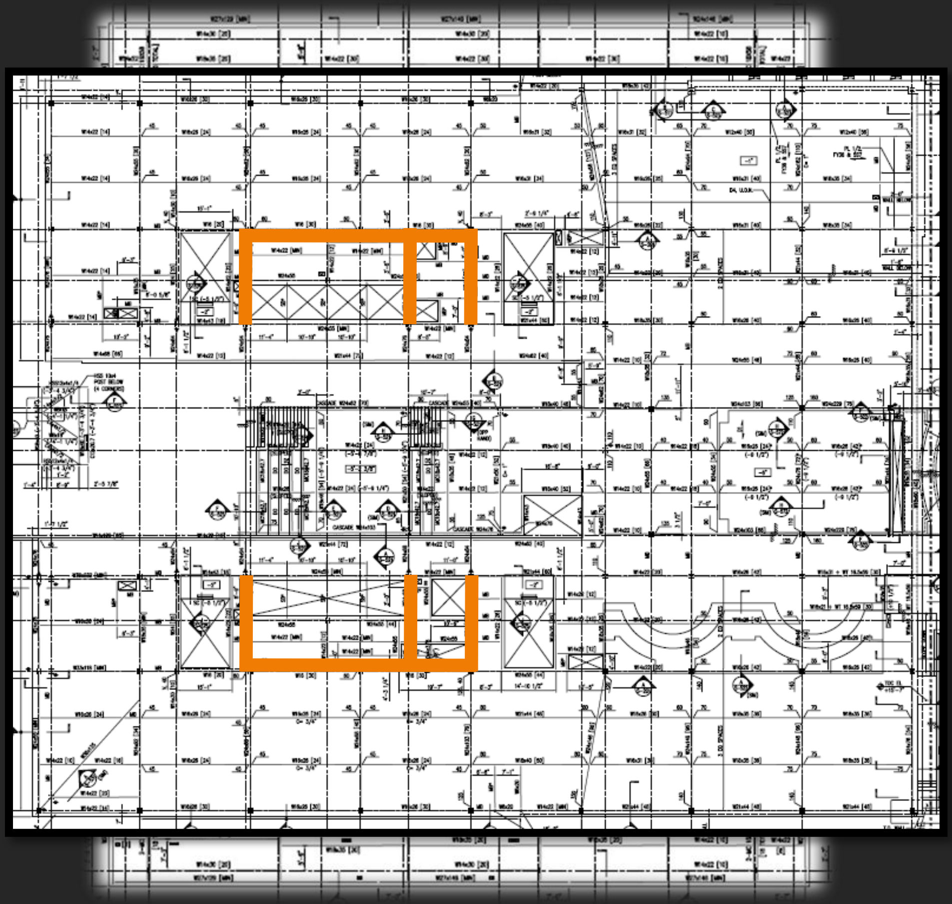


Existing Structural Systems

Lateral Force Resisting System

- Concentrically Braced Frame Core
    - Braces range from HSS 6x6x3/8” to HSS 16x8x1/2”





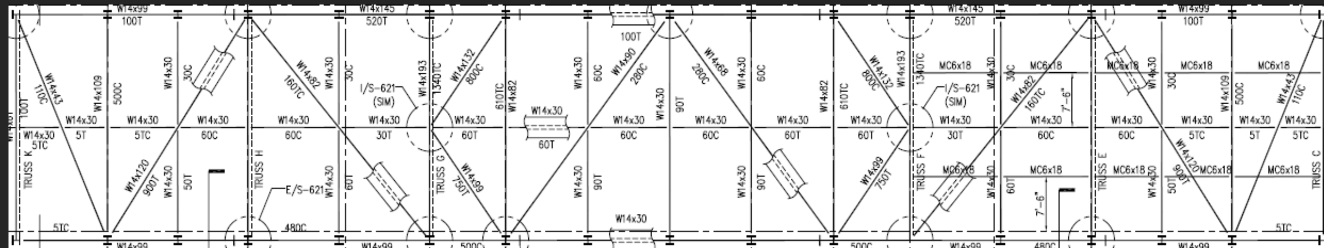
Construction Management Breadth Studies

Weight Comparison

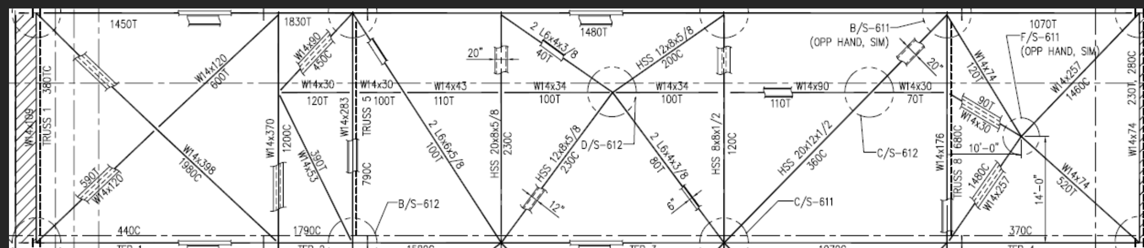
System	Thesis (kips)	Existing (kips)
Trusses	1380	1521
Perimeter Columns/Plate hangers	112	107
Braced Frame Core	1324	1304
Built-Up Girders	235	294
Total	**3051**	**3226**

New transfer system weighs 87 tons less than the existing design

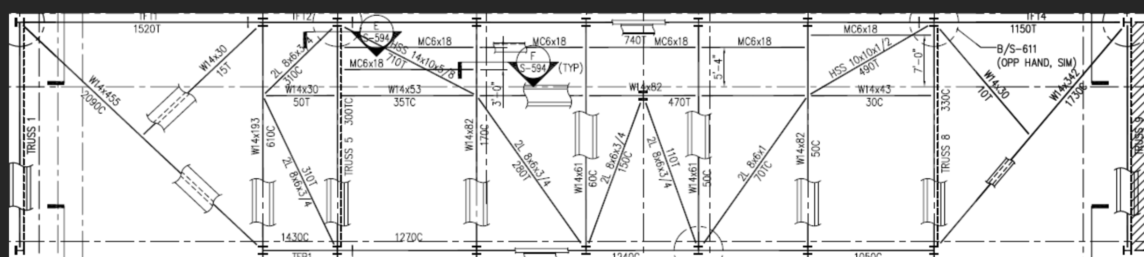
Existing Trusses



Truss 1 Equivalent



Truss 2 Equivalent



Truss 3 Equivalent