Helios Plaza

Houston, TX

Kevin Zinsmeister

Structural Option

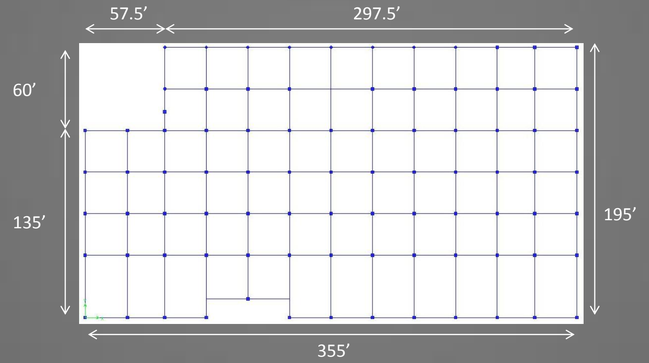
Advisor - Dr. Hanagan

Helios Plaza

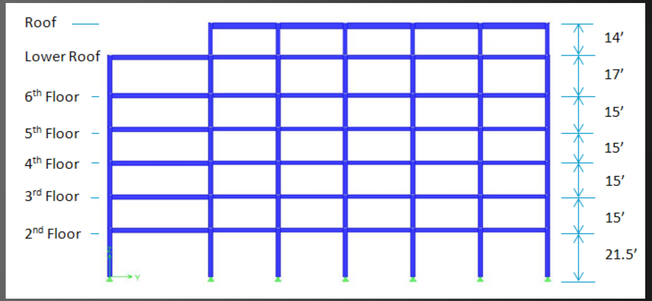
- Project Overview
- Existing Structural Conditions
- Proposal
- Gravity Redesign
- Lateral Redesign
- Steel Connection Design
- Architectural Breadth
- Cost and Schedule
- Conclusions

General Information

- Located in Houston, Texas' Energy Corridor Management District
- Headquarters for BP's IST and Energy Trading Divisions
- Composed of Offices, a Conference Center, and Trading Floors



- Rough Footprint of Building: 195' x 355'
- Overall Building Height of 113'
- Typical Story Height of 15'



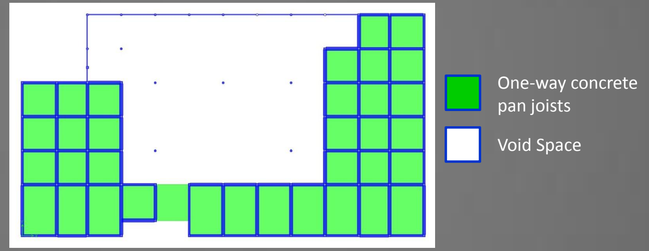
General Information

- Project Team
  - Owner – BP
  - Architect – Gensler
  - CM – Bovis Construction Ltd
  - Structural – Walter P. Moore & Associates, Inc.
  - MEP – I.A. Naman + Associates, Inc.

Exterior View of Southeast Corner

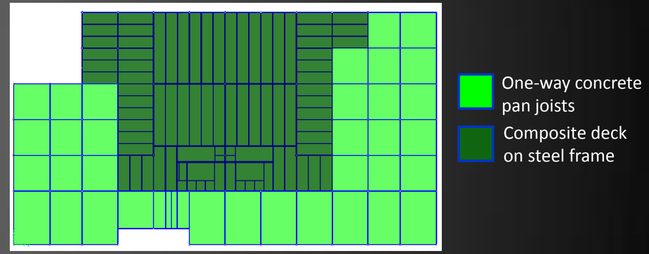
Existing Gravity System

- Two main systems employed
  - One-way pan joist concrete system for majority of building
    - Square concrete columns used for support
    - Post-tensioned girders used in long span situations



Floor Plan One Level Above Trading Floor

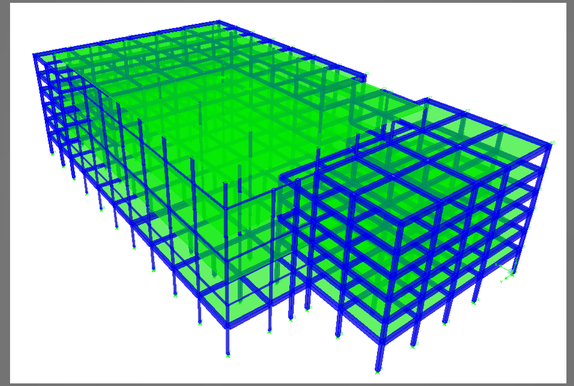
- Composite Deck with steel framing members for trading floors
  - Concrete filled circular HSS columns used for support
  - Castellated wide flanges used in long span situations



Floor Plan at Trading Floor Level

Existing Lateral System

- Lateral loads mainly resisted by ordinary concrete moment frames
- Moment connected HSS Members resist lateral loads in trading areas



3-D Representation of Lateral System

View of Trading Floor From Level Above

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Proposal

- Goals

1. Reduce the overall building weight
2. Eliminate the controlling seismic base shear in the East-West direction
3. Minimize floor plan impacts
4. Design aesthetically compatible braces
5. Reduce the construction schedule
6. Determine if foundation savings will offset increased steel structure cost

- Proposed Solution
  - Switch concrete superstructure to steel superstructure
  - Design braced frames to resist lateral loads
  - Maintain existing column layouts
  - Maintain existing steel portions of building

Tools

- Computer Modeling
  - RAM for gravity design
  - ETABS for lateral design confirmation
  - Revit for architectural rendering
- Design Guides
  - Vulcraft deck catalog
  - AISC Steel Construction Manual
  - AISC Seismic Design Guide

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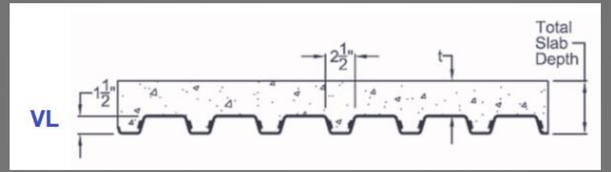
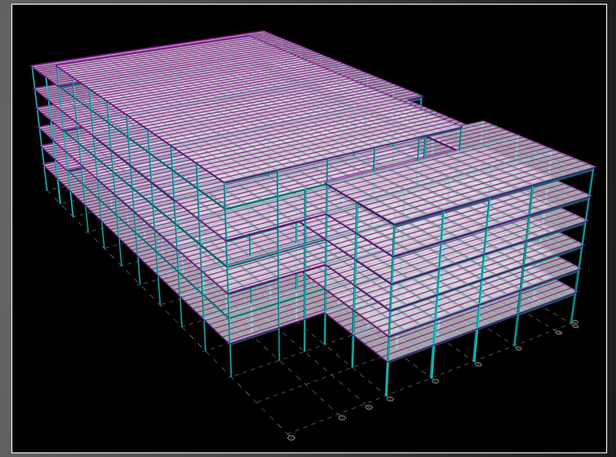
Deck Choice



- Vulcraft 1.5 VL with 3 ¼" LWC topping for 2 hour fire rating
- 10' and 9' spans for unshored construction
- 37 psf self-weight

RAM Model



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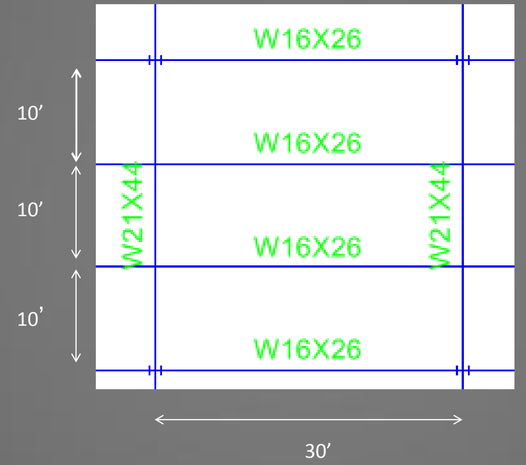
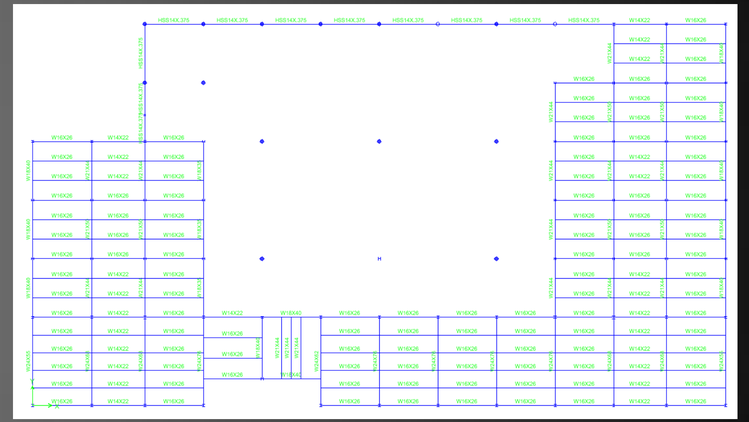
Typical Bay Framing Plan



3rd Floor Plan



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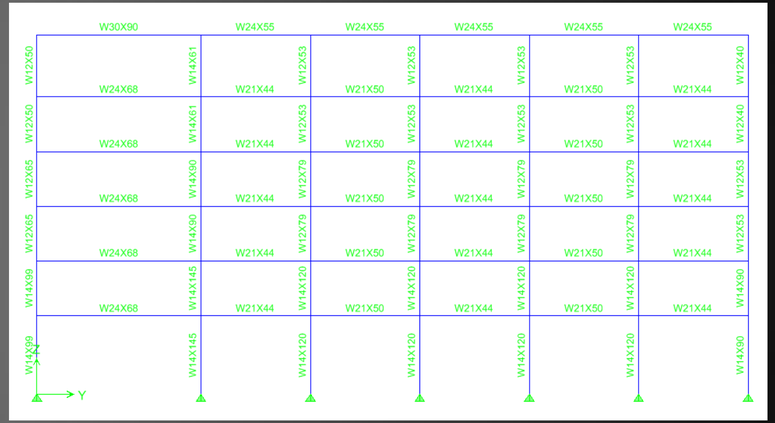
Column Design

- Column splices occur every other level for construction purposes
- W14 shapes used for first two floors
- W12 shapes mainly used for remaining floors
- Columns initially designed for gravity load only
- Columns checked for combined axial and bending load in ETABS after lateral loads determined

Typical Elevation



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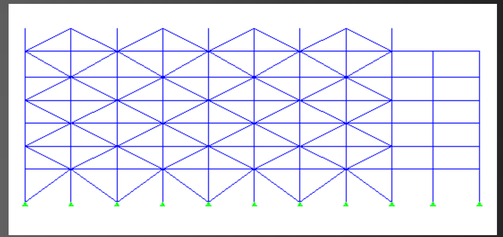
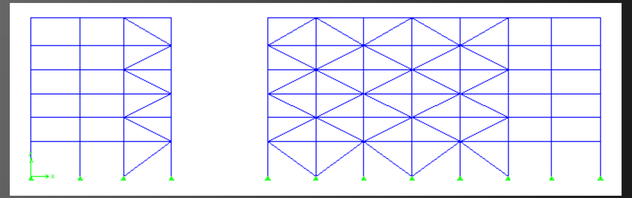
Brace Design

- East-West Frames
  - Braces designed by hand using AISC Seismic Provisions Guide as a reference
  - Initially designed with strength based on wind story shear forces
  - Once braces designed, preliminary building weight tabulated and new seismic story shears calculated
  - New seismic forces reduced, but still control for some levels
  - Braces redesigned in East-West direction for seismic provisions

Seismic Forces						
	Original			Redesign		
Level	Weight (k)	F_x (k)	Shear (k)	Weight (k)	F_x (k)	Shear (k)
roof	1089	78.8	78.8	1329	88.2	88.2
lower roof	2961	178.8	257.6	1918	106.9	195.2
6	6332	298.1	555.7	4447	194.9	390.1
5	4304	155.1	710.7	2255	76.3	466.4
4	6332	163.0	873.7	4455	109.0	575.4
3	4304	70.5	944.2	2270	35.9	611.3
2	7146	58.3	1002.5	4116	33.2	644.5
Total	32468	1002.5	-	20790	644.5	-





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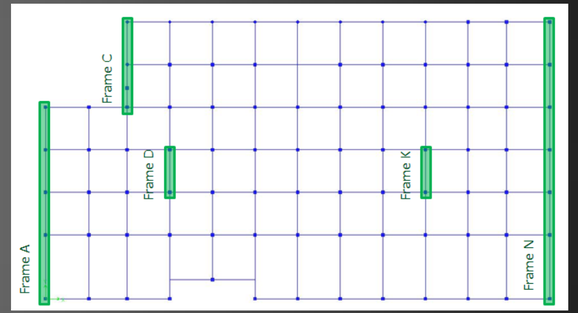
Brace Design

- North-South Frames
  - Preliminary sizes worked in strength design
  - Wind serviceability controls final design
  - Braces increased in size, but not enough stiffness achieved
  - Two interior x-braced frames added to limit roof deflection

- Allowable Deflection: H/400= 3.39”
- Preliminary Brace Design Deflection:=3.94”
- Final Brace Design Deflection= 3.24”

North-South Frames In Plan



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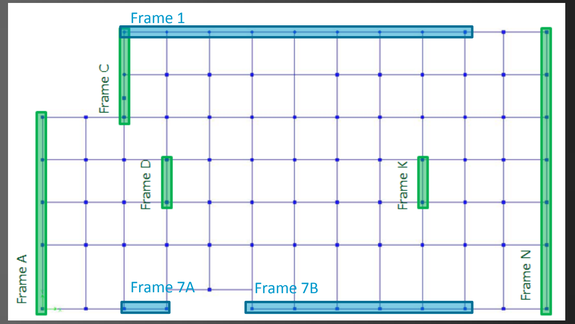
Brace Design

- Building Torsion
- Relative stiffness of frames computed for load distribution

1000 k Load In Y-Direction				
Frame	Δ	K (k/in)	$K_{relative}$	$K_{relative}$ (%)
A	9.650	103.6	0.2834	28.34
C	22.906	43.7	0.1194	11.94
D	31.919	31.3	0.0857	8.57
K	31.912	31.3	0.0857	8.57
N	6.423	155.7	0.4258	42.58
Total		365.6	1	100

1000 k Load In X-Direction				
Frame	Δ	K (k/in)	$K_{relative}$	$K_{relative}$ (%)
1	6.965	143.6	0.5934	59.34
7A	73.507	13.6	0.0562	5.62
7B	11.797	84.8	0.3504	35.04
Total		241.9	1	100

Frames In Plan



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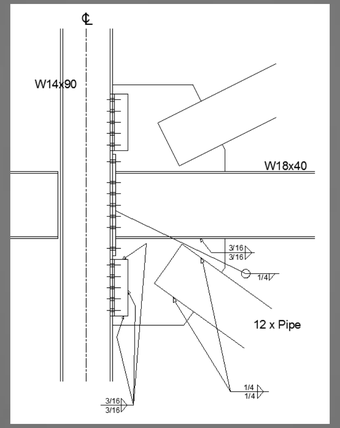
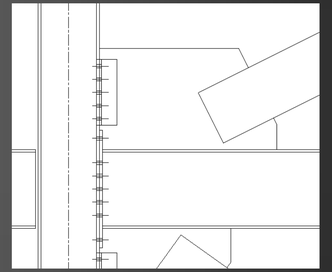
Steel Connection Area of Interest

- Interface of braces, columns and beams
- Designed for as many shop fitted connections as possible



Non-Eccentric Connection Layout

- Issues
- Long welds necessary for non-eccentric connection
- Gusset plate approximately 2’x3’-6”



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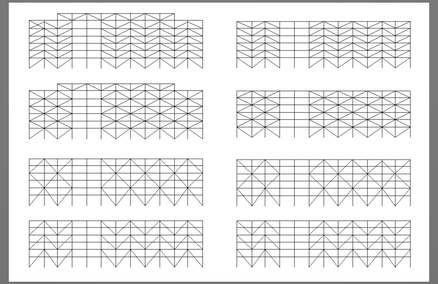
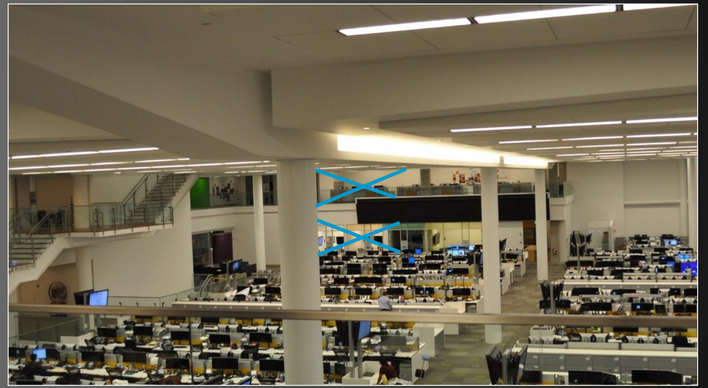
Floor Plan Impact

- Brace Locations
- Only exterior braces in the East-West direction
- Two interior braces in the North-South direction
- Interior braces located in minimal impact areas
  - Occur at the edges of the trading floor where only one levels floor plan is impacted
  - X-bracing used to limit number of bays impeded



Interior Brace Location



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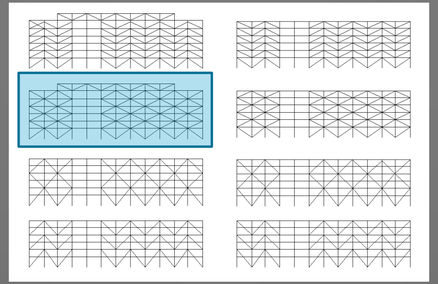
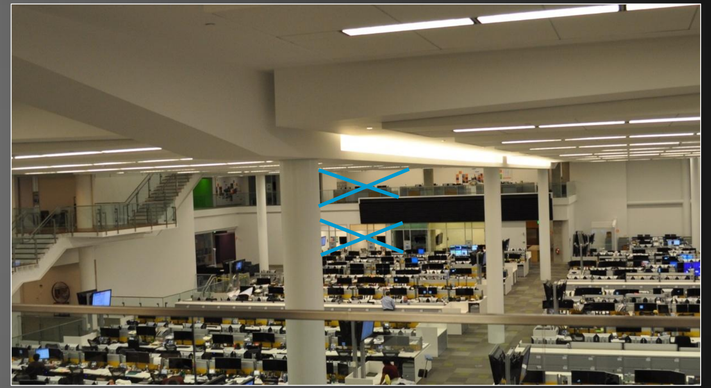


Interior Brace Location



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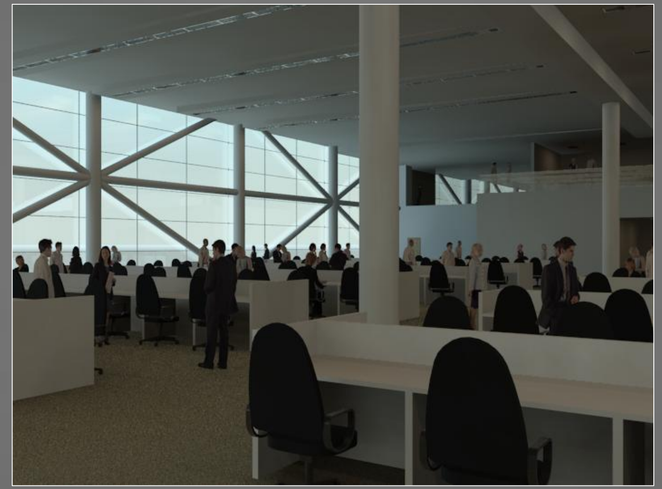
Interior Rendering



Similar Interior View

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Detailed Cost Breakdown

Existing Structure Cost Breakdown	
Description	Cost
Concrete	$ 1,733,912.15
Formwork	$ 2,128,486.74
Reinforcement	$ 509,997.90
Steel Members	$ 1,345,288.34
Decking	$ 169,344.96
Total	$ 5,887,030.09

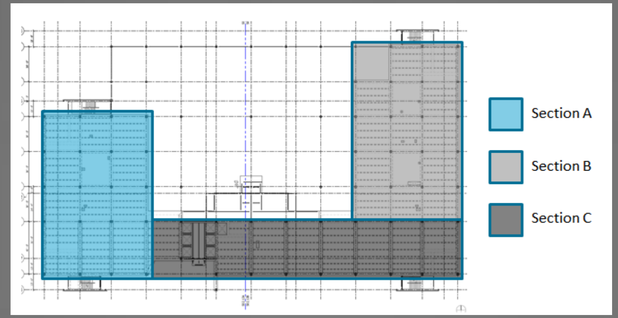
Redesign Cost Breakdown	
Description	Cost
Wide Flange Members	$ 3,402,132.71
Braces and HSS Members	$ 922,388.34
Shear Studs	$ 50,855.40
Decking	$ 805,674.65
Concrete (including formwork and reinforcement)	$ 976,387.92
Fireproofing	$ 709,220.76
Total	$ 6,866,659.78

Foundation Cost Breakdown

Foundation Savings			
	Concrete (CY)	Formwork (SFCA)	Cost
Original Design	2012	16131	$ 319,779.62
Redesign	1756	14355	$ 280,321.94
Savings	256	1776	$ 39,457.68

- Summary
- Increase in cost: $ 979,629.69
- Foundation reduction not enough to offset increase in superstructure cost
- Majority of cost increase due to fireproofing

Schedule Impact



- Existing Structure
- Broken down into three sectors for construction
- 8 crews typically used for most tasks
- Total number of construction days: 194

- Redesign
- 4 crews typically used for most tasks
- Crew sizes generally based on 2 crane assumption
- Total number of construction days: 143

- Total Savings
- 51 days of schedule
- 31 working days
- 992 man hours

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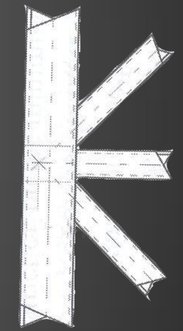
Conclusions

- Goals met:

1. Reduce the overall building weight
    - 36% reduction in weight
2. Eliminate the controlling seismic base shear in the East-West direction
    - Seismic base shear smaller than wind base shear, but seismic forces still control design of several floors
3. Minimize floor plan impacts
    - Two interior bays impeded
    - Large gusset plates could use reduction
4. Design aesthetically compatible braces
    - Similar cross-sections blend well with existing architecture
5. Reduce the construction schedule
    - 51 days of schedule saved
6. Determine if foundation savings will offset increased steel structure cost
    - Foundation savings account for only $ 39.457.68

Recommendations

- Recommendations:
    - Switch to chevron bracing to achieved more efficient brace connections; or,
    - Switch brace connections to slotted welds



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- A Special Thanks To:
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    - David Kinnaird – Coordinator
  - Gensler
    - Rives Taylor – General Consulting
  - Walter P. Moore & Associates, Inc.
    - Dennis Wittry – Project Document Delivery
  - The AE Faculty
  - Friends and family for their continued support

Questions/Comments

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Thank You

Any Questions/Comments?