

8TH STREET OFFICE BUILDING

Richmond, VA



Carol Gaertner | Spring 2010 | Structural | Professor M. Kevin Parfitt

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Building Overview

Existing Structural System

Project Goals

Structural Depth Study

Architectural Breadth Study



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Sustainable Breadth Study

Optimal Steel Lateral System

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Location

- Richmond, Virginia
- Adjacent to the northwest corner of Capitol Square

Size

- 307,178 ft²
- 4 stories of underground parking garage, 10 stories above grade, and mechanical penthouse

Occupancy

- General Assembly for approximately 5 years
- Various Commonwealth of Virginia agencies

Design Team

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Project Site



Capitol Square

Location

- Richmond, Virginia
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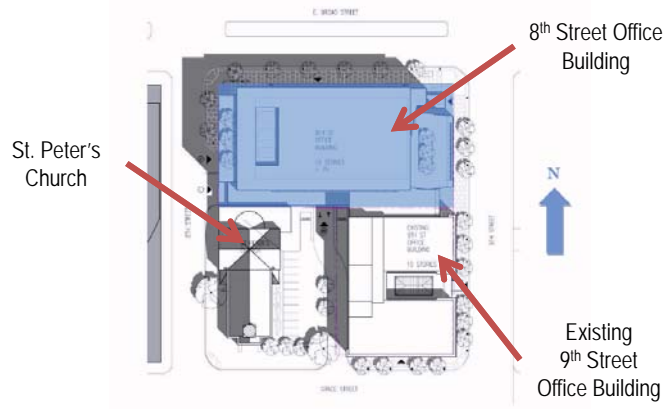
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Project Site

Capitol Square

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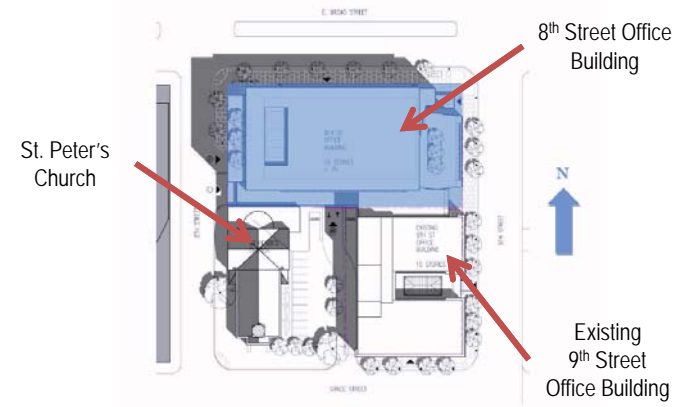
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Architectural Features

- Façade: angled glass curtain walls, precast concrete panels, aluminum
- Cantilevered standing seam stainless steel roof
- 3 landscaped terraces at the 3rd, 7th, and 10th floors



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Foundation

- 48" thick, 4,000 psi concrete mat foundation reinforced with #10 bars at 12" each way on the top and bottom

Underground Parking Garage

- 201 spaces
- Typical bay sizes of 20'-0" x 40'-6" and 20'-0" x 30'-0" with 8" thick, one way concrete slabs spanning the short direction

Steel Superstructure

- Same typical bay sizes as the parking garage
- Composite floor system of 3 ¼" lightweight concrete topping on 2" deep, 18 gage metal deck
- Composite beams are typically W16x31, W18x35, W18x40
- W14 columns spliced every three floors

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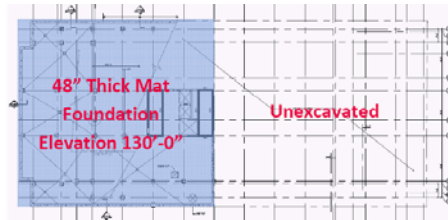
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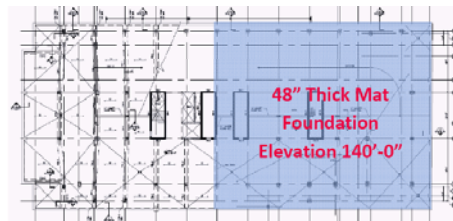


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4th Parking
Garage Level
below ground

3rd Parking
Garage Level
below ground



Foundation

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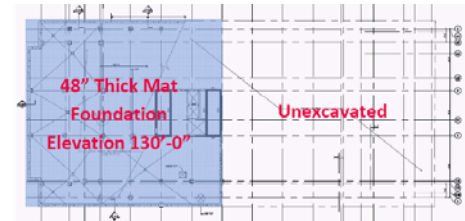
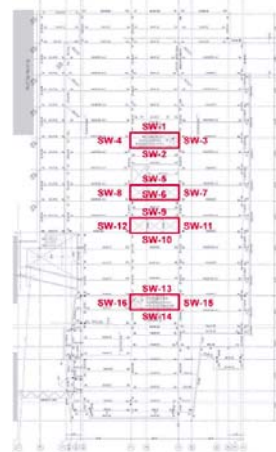
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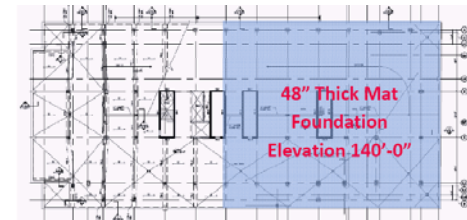
Lateral System

- 16 reinforced concrete shear walls surrounding four transportation cores
- 12" thick, reinforced horizontally with #6 bars and vertically with #8 bars



4th Parking
Garage Level
below ground

3rd Parking
Garage Level
below ground



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Structural Depth Study

- Investigate the following options for a steel lateral system:
 - Steel Plate Shear Walls
 - Braced Frames
 - Moment Frames
 - Dual System
- Design two of the systems in depth.
- Incorporate optimal system with new architecture and loads.

Architectural Breadth Study

- Revise the service core layout in order to maximize occupiable space.

Sustainable Breadth Study

- Reduce stormwater runoff and demand for water through green roofs and a rainwater harvesting system.

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General Criteria and Loads

- All material properties designated by the design structural engineers:
 - W-shapes: ASTM A992, Grade 50
 - Rectangular HSS shapes: ASTM A500, Grade B, $F_y = 46$ ksi
- Columns to be W14 shapes
- Total displacement to be limited to 1/400 of the total building height (5.29 inches)
- Gravity Loads

Gravity Loads Utilized for the Design of the Lateral Systems		PSF
Dead Loads		
2" Composite Metal Deck with 3 1/2" Lightweight Concrete Slab		41
Self Weight of Steel Framing		8
Curtain Walls and Precast Concrete Panels		25
Mechanical Rooms (Inclusive)		150
Roof/Terrace (Inclusive)		100
Atrium (Inclusive)		60
Superimposed Dead Loads		
Fireproofing		2
Finishes		10
Partitions		20
Ceiling		5
Mechanical/Electrical/Plumbing		5
Live Loads		
Lobbies & First Floor Corridors		100
Corridors above First Floor		100*
Assembly Areas		100
Offices		50
Ordinary Roof		30*
Roofs used for Roof Gardens or Assembly Purposes		100

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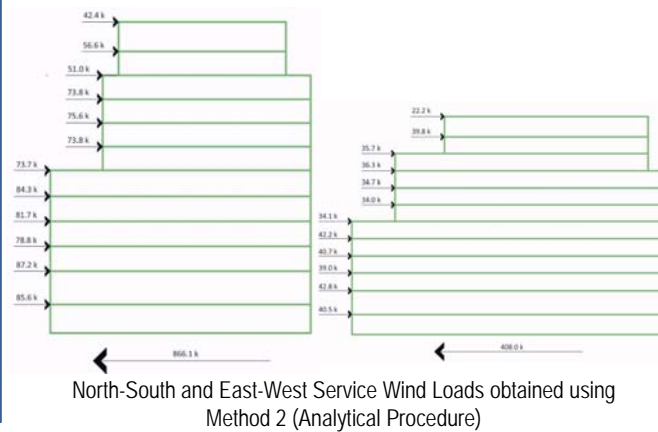
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Lateral Loads



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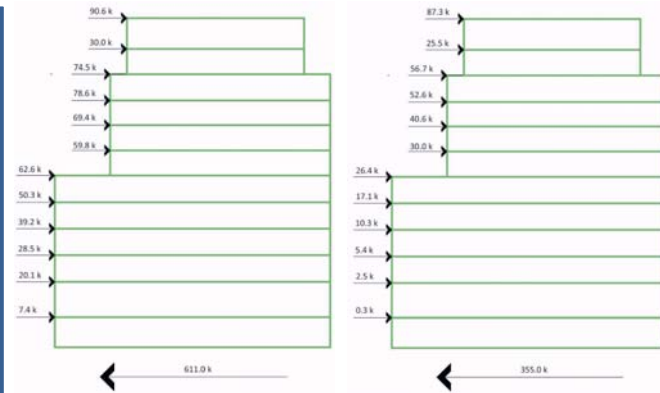
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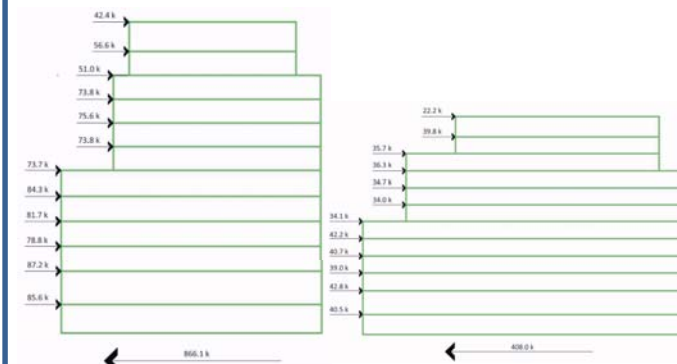


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Ultimate Seismic Loads for Braced Frames and Moment Frames obtained using the Equivalent Lateral Force Procedure

- Lateral Loads



North-South and East-West Service Wind Loads obtained using Method 2 (Analytical Procedure)

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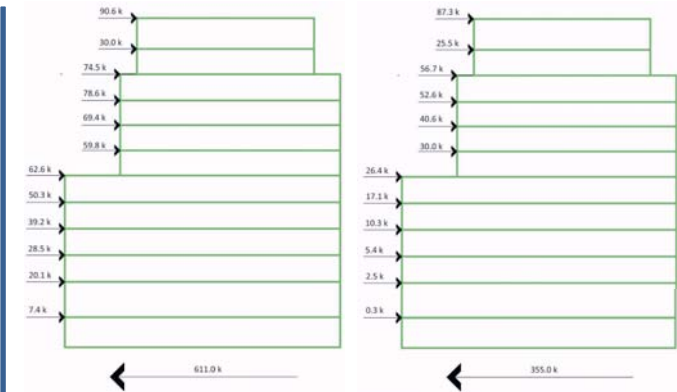
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Steel Plate Shear Walls

- Diagonal tension in unstiffened, slender web plates
- Advantages:
 - Economical
 - Reduced wall thickness
 - Quick construction time
- Not ideal because locations are limited to the four transportation cores.
 - Drift control
 - Torsional resistance
 - Openings



Ultimate Seismic Loads for Braced Frames and Moment Frames obtained using the Equivalent Lateral Force Procedure

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Moment Frames

- Investigated primarily due to compatibility with open floor plans and openings.
- General Disadvantages:
 - Complex connections
 - More steel tonnage required to achieve adequate stiffness
- Not ideal due to large floor to floor heights (more than 18' for the second story).
 - Unable to meet recommended slenderness limit of $KL/r = 200$
 - Inefficient
 - Extra care to avoid damage

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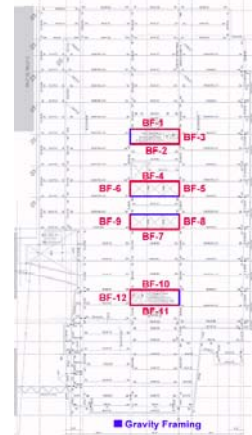
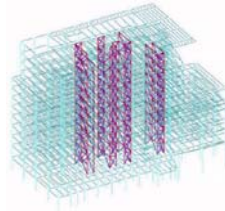
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Braced Frames

- Similar advantages to Steel Plate Shear Walls but more able to handle openings.
- RAM Structural System
 - Design Process
 - Design Assumptions



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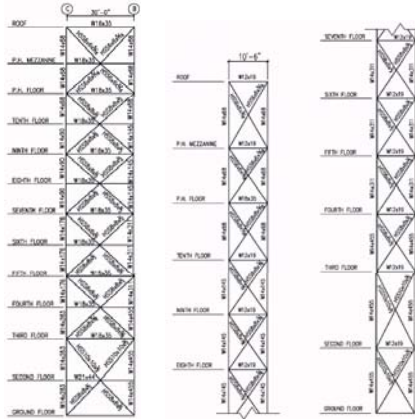
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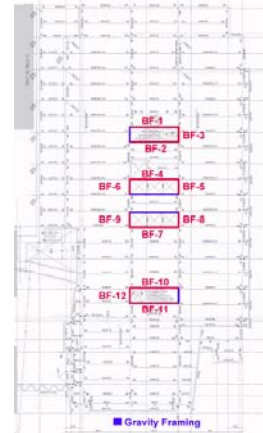
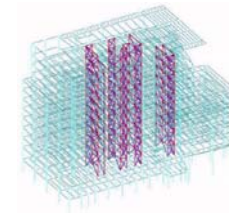
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- Governed by required drift ratio of 0.00625.
- Typical finalized designs



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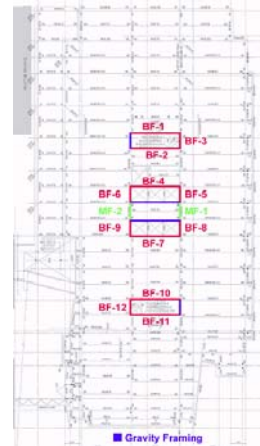
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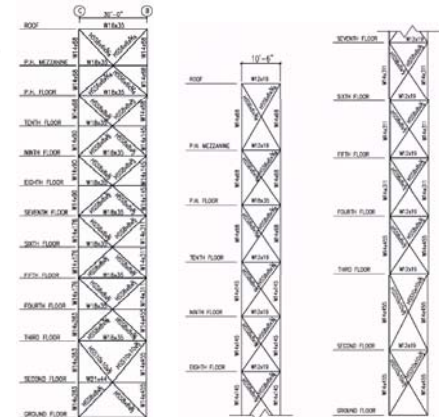
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Dual System

- Selection of moment frame locations
- 2 options
 1. Keep braced frames previously designed for strength.
 2. Keep braced frames previously finalized for drift control.
- Same design assumptions as before in RAM Structural System



- Governed by required drift ratio of 0.00625.
- Typical finalized designs

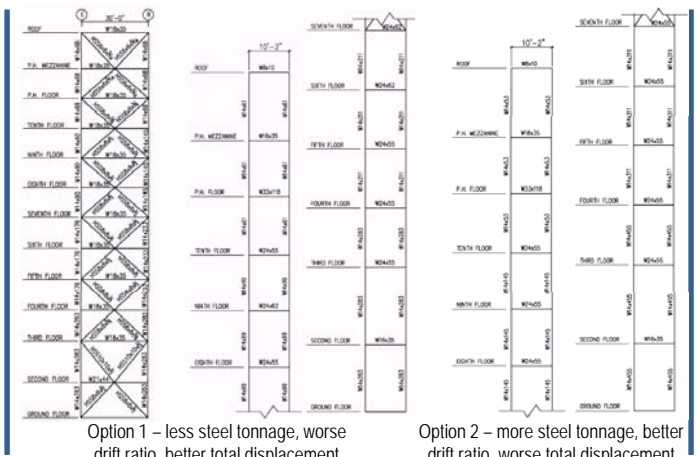


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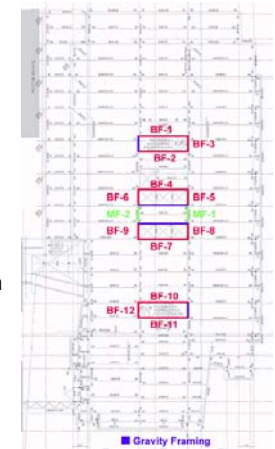
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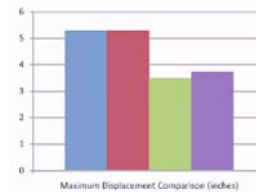
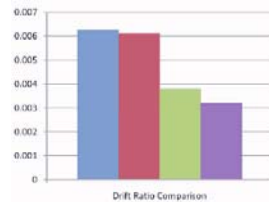
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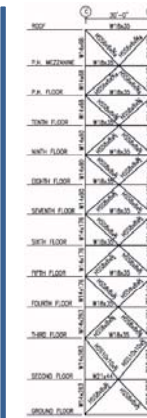
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Comparisons and Conclusions

- Steel Plate Shear Walls – not compatible with architecture ✘
- Moment Frames – not compatible with floor-to-floor heights ✘
- Braced Frames – governed by drift ✘
- Dual Systems – comparable drift control, Option 1 uses less steel ★



■ Allowable
 ■ Braced Frames
 ■ Dual System 1
 ■ Dual System 2



Option 1 – less steel tonnage, worse drift ratio, better total displacement



Option 2 – more steel tonnage, better drift ratio, worse total displacement

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ARCHITECTURAL BREADTH STUDY

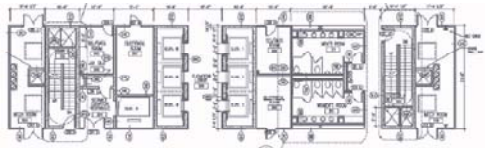
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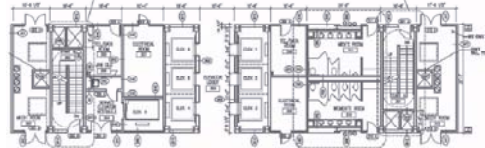
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1,440 square feet useable space gained for the tenants by eliminating the corridor between the restrooms and Stair A on the 3rd through the 9th floors.



Original
3rd Floor Plan



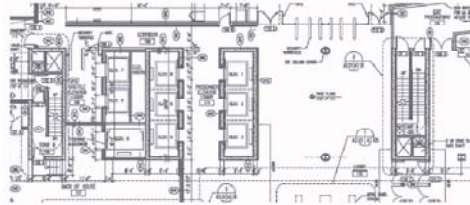
Revised
3rd Floor Plan

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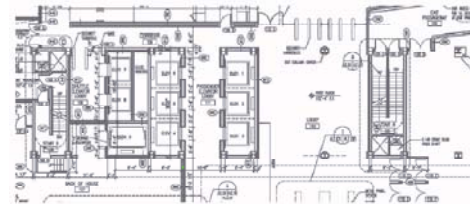
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Original
1st Floor Plan

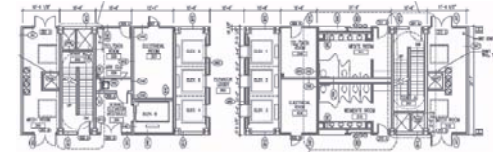


Revised
1st Floor Plan

1,440 square feet useable space gained for the tenants by eliminating the corridor between the restrooms and Stair A on the 3rd through the 9th floors.



Original
3rd Floor Plan



Revised
3rd Floor Plan

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SUSTAINABLE BREADTH STUDY

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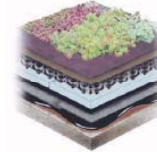
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Green Roof

- Extensive Garden Roof Assembly produced by Hydrotech, Inc.
- Utilized on the 3rd, 7th, and 10th floor terraces (8051 square feet)
- Benefits



Element	MM6125	Root Stop with Hydroflex 30	Gardendrain GR30 (filled)	Filter Fabric	Intensive Soil	Sedum Carpet	Total
Profile Height (inches)	0.25	0.1	1.2	0.01	4.0	n/a	5.56
Saturated Weight (psf)	1.5	0.8	3.8	0.03	27.0	5.0	38.13

Rainwater Harvest System

- All non-green roof area considered
- 3 tanks sized at 1,000 gallons each
- 13.8% savings in water demand for the sanitary system

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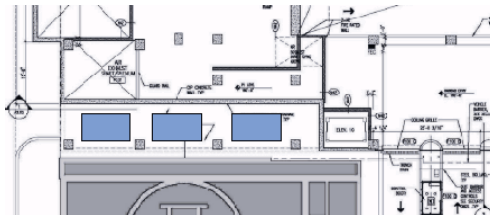
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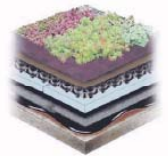
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- To be located in the currently unexcavated area of the 1st parking garage level below grade adjacent to Elevator 10 and an air exhaust shaft/plenum



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OPTIMAL STEEL LATERAL SYSTEM

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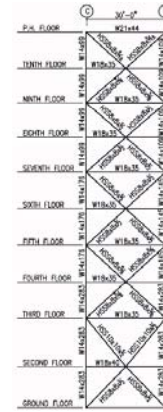
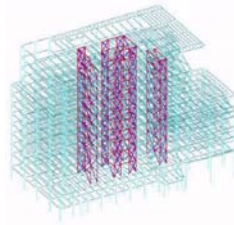
Questions & Comments



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Dual System: Option 1

- Revised architecture resulted in a 6'-0" shift west of braced frames 10, 11, and 12.
- Terrace loads did not need to be revised for the green roof loads.
- Drift ratio at roof = 0.0038
- Total displacement = 3.81 inches



Braced Frame 11

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Steel Lateral System Analyses

- Steel Plate Shear Walls and Moment Frames are incompatible with the architecture of the 8th Street Office Building.
- Braced Frames were governed by drift requirements and displacement recommendations.
- Dual systems of both braced and moment frames are ideal.

Architectural Analysis

- It is possible to gain 1,440 square feet of useable space by redesigning the overall service core.
- Parking spaces, restrooms, and means of egress were maintained.

Sustainable Analysis

- The designed Hydrotech Extensive Garden Roof Assembly can hold 1.57 inches of moisture over 8,051 square feet.
- The rainwater collection tanks can save 13.8% of the sanitary system water demand.

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