

University of Maryland Dorm Building 7

6801 Preinkert Drive College Park, MD 20742

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Structural Option MAE/BAE
Advisor: Dr. Ali Memari
Spring 2009



Presentation Outline

1) Introduction & Building Overview
   - Building Statistics
   - Architecture
   - Existing Structure Overview
2) Structural Depth Study
   - Thesis Goals
   - Design Codes
   - Computer Modeling
   - Gravity Design
   - Gravity Connections
   - Lateral Procedure and Loads
   - Lateral Design
   - Lateral Connections
   - Alternatives and Implications
   - Foundation Considerations
   - Goal Summary
3) Green Roof Breadth Study
   - Material and Considerations
   - Green Roof Layout and Design
   - Water Collection System Design
   - LEED and Impacts
4) Conclusions & Recommendations
5) Questions?

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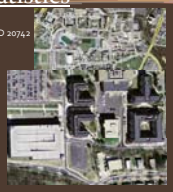
Building Statistics



Location: 6801 Preinkert Drive College Park, MD 20742

Architecture: U-Shape Plan
9 Stories including the Terrace Level
Units are designed for 2-4 people
Total Height 94'

Building Use: Dormitory/Apartments
Office Space for Building Housing

Size: 133,000 Square Feet

Cost: $23.5 Million

Structure: Light-gage Bearing walls and Shear walls with Concrete Columns and Shear walls

MEP: Each unit is separately heated and cooled by 111 rooftop mechanical units

LEED: Currently approaching a LEED Gold Standard

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Architecture of Building 7

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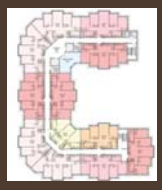
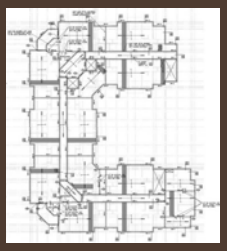


Current Existing Structure



- Perimeter and Corridor Bear walls
  - Upper 6 Floors
  - 16 gage studs at 16-24" OC
- Concrete Columns and Girders
  - Lower two Floors
  - Beams:
    - 16-24" deep
    - 18-36" wide
  - Columns
    - 14" wide
    - 18-64" deep
- Hambro Composite Joists
  - 3" Conc. slab for upper floors
    - 16" deep joist in Apt.
    - 8" deep joist in Corridor
  - 5" Conc. Slab on lover floors

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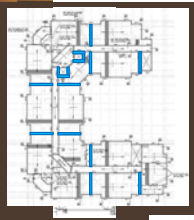

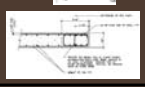

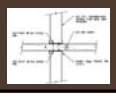

- Lateral System
  - 16 Shear walls
    - 7 in the East-West Direction
    - 9 in the North-South Direction
  - Located between apartments
- Concrete Shear walls: Lower 2 floors
  - Upper 6 Floors
  - 16 gage studs at 16-24" OC

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Thesis Proposal Goals

- Design an overall structure made using structural steel and limit use of propriety systems.
- Design a gravity system that does not require a change in the building height while still being acceptable.
- Move the location of Building 7 to a high seismic Region to better understand and work with seismic requirements in detail. (San Diego, CA)
- Pick a single lateral system that will work for the new location and optimize it.

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Design Standards and Codes

- Steel Design
  - AISC Steel Construction Manual, 13th Edition
  - AISC Seismic Design Manual (AISC 327-05)
  - 2005 AISC Seismic Provisions (AISC 341-05)
  - AISC Steel Design Guide 19: Fire Resistance of Structural Framing
  - Vulcraft Steel Roof and Deck Catalog

- Other References
  - Minimum Design Loads for Buildings (ASCE 7-05)
  - International Building Code 2006

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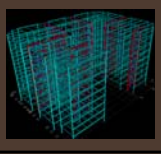
RAM Computer Modeling

Assumptions and Considerations:

- Both Gravity and Lateral Systems were modeled
- Diaphragms assumed to be perfectly rigid
- Columns were modeled with a fixed base to help with drift.
- All proper gravity and lateral load combinations were generated for the model
- P-Delta effects were taken into account according to ASCE 7 -05
- Story shears applied at 5% eccentricity to account for accidental torsion



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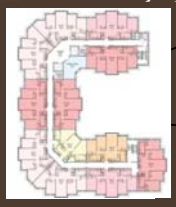
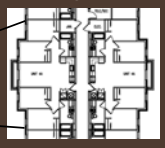
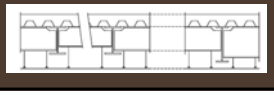
Gravity System Design





- 2 Bays vs. Double-Loaded Corridor
  - Depth of members
  - Space for MEP
  - Quantity of columns



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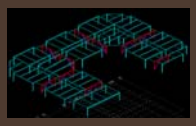
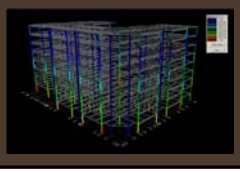
Gravity System Design

Beams and Girders
- Max spacing of 9'-6" typical
- 3VL21 composite deck
- Light-weight
- Total slab thickness of 6.25"
- Table 3-19 (composite W-shapes)



Gravity Columns
- Proper live load reduction used
- Spliced every other level
- Limited sizes for repetition
- Table 4-1and Table 6-1



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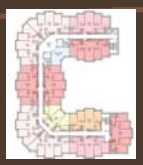
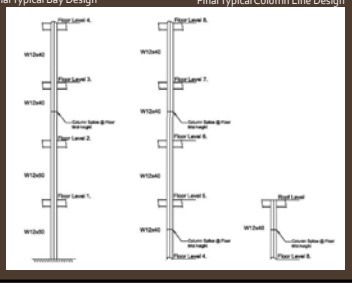


Gravity System Design

Final Typical Bay Design

Final Typical Column Line Design



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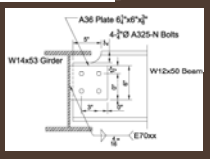
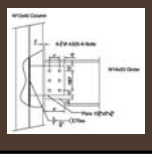
Gravity Connections

Beam to Girder Connection :
- Shear Tab design
- Single Top Cope Beam
- Bolted to the beam and welded to the





Girder to Column Connection :
- Extended shear tab design
- Cope at the bottom for placing concerns
- Bolted to the girder and welded to the column

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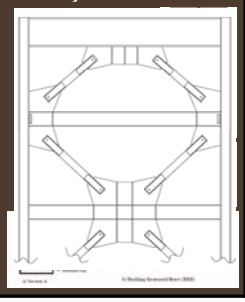
Possible Lateral Systems

Considered Viable Lateral Systems
- Special Concentric Braced Frames
- Special Moment Frames
- Special Plate Shear walls
- Buckling Restrained Braced Frames

Chosen Lateral System: SCBF
- Reasons
  - Most commonly used
  - Initial available space for them
  - Multiple bracing configurations
  - No specialty software required
  - Many connection options



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Acceptable Lateral Procedure

Checks:
- Horizontal Irregularity Check
- Vertical irregularity Check
- With SDC D
  - Equivalent Lateral Force Procedure is Acceptable

Horizontal Structural Irregularities

Type	Irregularity	Comment	Status
1a	Torsional	After Modeling structure it can been concluded that this irregularity does not exist.	Good
2	Reentrant Corner	This irregularity does exist due to the U-Shape of the plans but ELFP is allowed, a 25% force increase for the connections between the diaphragm and the vertical elements are required.	Not Met
3	Diaphragm Discontinuity	Irregularity does not exist by inspection of the drawings.	Good
4	Out of Plane Offsets	No vertical element out of plane offsets exists by inspection of the drawing.	Good
5	Non Parallel System	All lateral force resisting systems are parallel to the orthogonal axes.	Good

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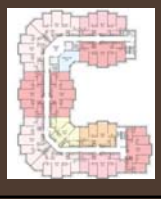

Seismic Loads

Criteria:
- SDC D
- R=6
- I=1.0

Building Periods
- Tx = 0.907 seconds
- Ty = 0.732 seconds

Vertical Force Distribution E-W Direction

Floor	Height (Ft.)	Weight (Kips)	Cvx	Fx (kips)	Story Shear
Roof	90	2145.00	0.24	398.08	398.08
8	80	1700.00	0.17	280.44	678.52
7	70	1700.00	0.15	245.39	923.91
6	60	1700.00	0.13	210.33	1134.24
5	50	1700.00	0.11	175.28	1309.51
4	40	1700.00	0.08	140.22	1449.73
3	30	1700.00	0.06	105.17	1554.90
2	20	1700.00	0.04	70.11	1625.01
1	10	1700.00	0.02	35.06	1660.06
Total Weight		15745	kips		
Seismic Base Shear		1660.06	kips		
Overturning Moment		107,339.65	kip-ft		

Vertical Force Distribution N-S Direction

floor	Height (Ft.)	Weight (Kips)	Cvx	Fx (kips)	Story Shear
Roof	90	2145.00	0.24	467.42	467.42
8	80	1700.00	0.17	329.29	796.70
7	70	1700.00	0.15	288.12	1084.83
6	60	1700.00	0.13	246.96	1331.79
5	50	1700.00	0.11	205.80	1537.59
4	40	1700.00	0.08	164.64	1702.24
3	30	1700.00	0.06	123.48	1825.72
2	20	1700.00	0.04	82.32	1908.04
1	10	1700.00	0.02	41.16	1949.20
Total Weight		15745	kips		
Seismic Base Shear		1949.20	kips		
Overturning Moment		126,035.22	kip-ft		

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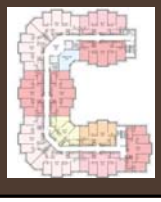
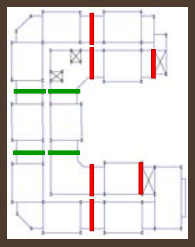


Lateral System Design

Location of SCBF
- Limited to within walls due to braces
- No perimeter frames
- Original locations the best solution

Quantity in each Direction
- Reduced the number from existing
- 4 in the East-West Direction
- 6 in the North-South Direction



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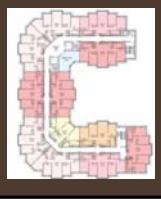
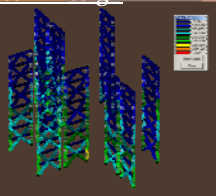


Lateral System Design

Key Load Combinations
- 1.2D + 1.6W + L + 0.5(Lr or S or R)
- (1.2 + 0.2SDS)D + ρQE + L + 0.2S
- (0.9 – 0.2SDS)D + ρQE + 1.6H

Adjusting Members
1. Increase brace sizes
2. Increase column sizes
3. Increase beam sizes

Member Design
- Lower stories controlled by strength
  - 60-75%capacity of members
- Upper Stories controlled by drift
  - 15-20% capacity of members



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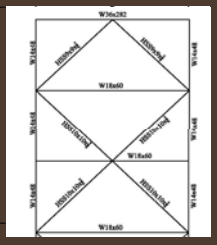
Lateral System Design

Typical SCBF Design



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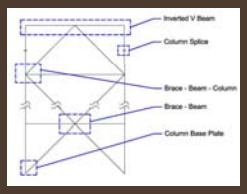
Lateral Connections & Detailing

Typical Lateral Connections
- 5 Standard/critical connections
- Designed per AISC 341-05
- Loads determined by ASCE 7-05



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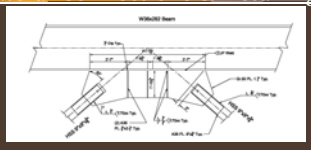
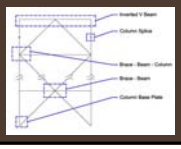
Lateral Connections & Detailing





Inverted-V Design

- Beam takes unbalanced Load
- Gusset plate requires Stiffeners
- Gusset plate attached at the shop
- Reinforced HSS brace at ends
- Yield line on gusset plate

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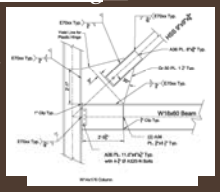
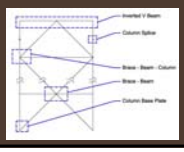
Lateral Detailing

Column to Splice & Column Design

- Use Welded field splice plate
- Weld access holes per Spec. J1.6
- Reinforced HSS capacity for capacity
- Design 8 for beam to form a story
- All welded connection except beam shear tab
- Yield line on gusset plate





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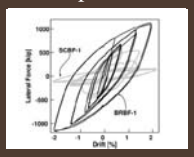
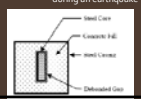
Alternative Structural Options

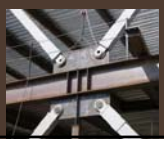
Two Alternatives Considered:
- Alternate top single story X for frames
- Use of Buckling Restrained Braced Frames

Alternate Top Story
- Eliminates the inverted-V and decreases the beam size to W18x60
- Braces became slightly smaller
- Helps with the drift

Buckling Restrained brace Frames
- Slight improvement at drift control
- Smaller connections
- Can act as true pined-pined member
- More costly but less non-structural damage during an earthquake







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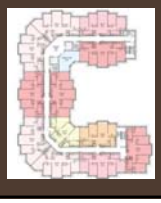
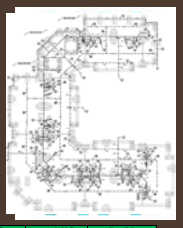


Foundation Considerations

Implications
- Change in structural system
  - Different layout from the original
- Change in location
  - Soil interaction during and Earthquake
  - Foundation ties
  - Dynamic ground movement and stresses
  - Energy dissipation



	Load (Kips)	Soil Bearing (ksf)	Area needed (sf)	Size (ft.)
Typical Exterior Column	355.00	5.56	63.90	8
Typical Interior Column	324.00	5.56	58.32	8
Corridor bend Column	600.00	5.56	108.00	10

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Structural Goal Summary

1.) Design an overall structure made using structural steel and limit use of propriety systems.

Outcome: The new steel design achieves this very well. (4.5/5)

2.) Design a gravity system that does not require a change in the building height while still being acceptable.

Outcome: The design follows this but has limitations/issues (3/5)

3.) Move the location of Building 7 to a high seismic Region to better understand and work with seismic requirements in detail. (San Diego, CA)

Outcome: The move allowed for a more challenging design (5/5)

4.) Pick a single lateral system that will work for the new location and optimize it.

Outcome: The system works but has issues with the code (3.5/5)

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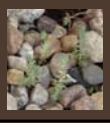
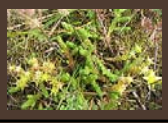
Green Roof Study

Reasons for a Green Roof
- Original Building 7 did not have one due to cost concerns
- They can reduce the heat island effect and the use of excess gray water

Chosen Roof Type
- Extensive Green Roof
  - Very self –sustaining
  - Minimum yearly maintenance
  - Lighter and for non-accessible roofs

Plant types
- Wanted a low maintenance and acceptable in both locations
  - Sedum species along with mosses
  - Readily available in both locations





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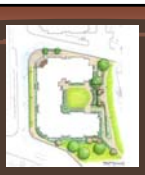
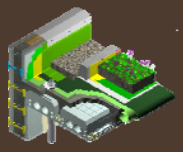
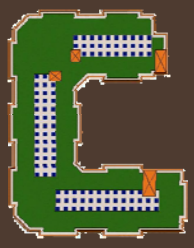


Green Roof Layout

Layout
- Mechanical units moved to 3 locations
- 1' Gravel around the perimeter
- Gravel around the mechanical units

Details
- 2 layers of rubber membrane for water
- Filtering mesh for water runoff
- 3" soil for the plant life





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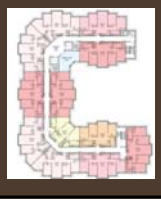
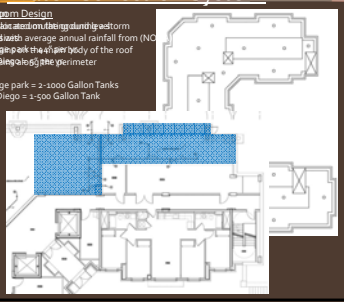


Water Collection System

Drainage System Design
- Based on location of the gutters and downspouts
- Tanks sized with average annual rainfall from (NC
  - College park the 4th per b
  - San Diego is the p
- Tank sizes:
  - College park = 2-1000 Gallon Tanks
  - San Diego = 1-500 Gallon Tank



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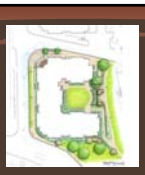
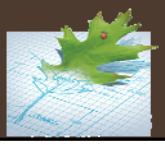


LEED Considerations

Initial LEED Goals and Design
- Become a minimum of LEED certified
  - Currently 1 Point away from LEED Gold
- Residents need to take a class on how to keep the building more efficient and green

Points Gained by The Green Roof
- Reduction in the heat island effect
  - Gain = 1 Point
- The increase usage of gray water to reduce the building's consumption
  - Gain = 1 Point

Other Green Advantages from the Design
- The usage of structural steel
  - Consists mostly of recycled scrap steel



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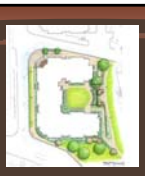

Green Roof Summary

1.) The green roof was designed for both locations and is acceptable for both

Outcome: (4/5)

2.) The water collection system is acceptable for both locations but is greener for College Park MD

Outcome: (5/5)

3.) The redesign reduces in the impact on the environment and also bring the LEED rating to Gold.

Outcome: (5/5)

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Conclusions & Recommendations

1.) The structural system meets the redesign goals for both gravity and lateral systems and is a good choice for a high seismic region

Recommendations:

- Implement the alternative structural alternatives
- Use a modal analysis procedure so to obtain a base shear reduction
- Use expansion joints to separate the U-shape into 3 buildings

2.) The green roof and water collection system reduces in the impact on the environment and also bring the LEED rating to Gold.

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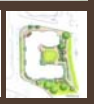

Acknowledgements

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A special thanks to my family and friends who have all provided me with guidance and support these past years.

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Questions ?

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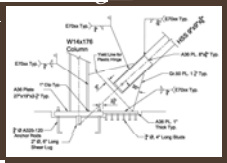
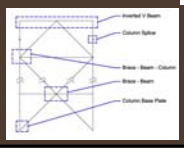
Lateral Detailing

Brace & Column to Base Plate Design

- Uniform method to eliminate moments
- Anchors around the perimeter to generate a large inertia
- Shear Lug to transfer shear
- Recessed base plate in foundation for flat surface for architecture





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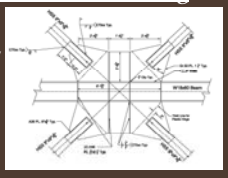
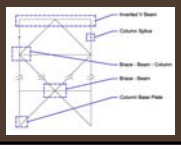
Lateral Connections & Detailing

Brace to Beam Midspan Design

- CJP Weld to reduce weld length
- Plate & Beam requires Stiffeners
- Plate angles controlled by geometry and Whitney Section
- Gr. 50 Plate allowed per AISC Spec.
- Yield line on gusset plate





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Lateral Connections & Detailing

Seismic Criteria for SCBF Design		
Criteria	Value	Code Reference
Occupancy Category	II	Table 1.1
Importance Factor	1.000	Table 11.5-1
Seismic Category	D	ASCE 7-05 Section 11.6
Site Class	C	Geotechnical Report
Spectral Acceleration for Short Periods (Ss)	1.572	www.usgs.org
Spectral Acceleration for 1 Second Periods (S1)	0.617	www.usgs.org
Site Coefficient, Fa	1.000	ASCE 7-05 Table 11.4-1
Site Coefficient, Fv	1.300	ASCE 7-05 Table 11.4-2
Seismic Design Category	D	ASCE 7-05 Table 11.6-1,2
R Factor	6.000	ASCE 7-05 Table 12.2-1 # B3
S	1.572	ASCE 7-05 Equation 11.4-1
S	0.802	ASCE 7-05 Equation 11.4-2
S	1.048	ASCE 7-05 Equation 11.4-3
S	0.535	ASCE 7-05 Equation 11.4-3
Deflection Amplification Cd	5.00	ASCE 7-05 Table 12.2-1 # B3
Overstrength Factor	2.00	ASCE 7-05 Table 12.2-1 # B3

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Lateral Connections & Detailing

Soft Story Check for SCBF N-S Direction

Story	Story Drift	Drift Ratio	0.7x the Story Drift Ratio	0.8x the Story Drift Ratio	Avg. Story Drift Ratio of Next 3 Stories	Soft Story Issue
Roof	0.494	0.0494	0.0346	0.0395	--	No
8	0.487	0.0487	0.0341	0.0389	--	No
7	0.441	0.0441	0.0309	0.0353	--	No
6	0.433	0.0433	0.0303	0.0346	0.0474	No
5	0.364	0.0364	0.0255	0.0291	0.0454	No
4	0.388	0.0388	0.0272	0.0311	0.0413	No
3	0.275	0.0275	0.0193	0.0220	0.0335	No
2	0.257	0.0257	0.0180	0.0206	0.0343	No
1	0.097	0.0097	0.0068	0.0077	0.0307	No

Soft Story Check for SCBF E-W Direction

Story	Story Drift	Drift Ratio	0.7x the Story Drift Ratio	0.8x the Story Drift Ratio	Avg. Story Drift Ratio of Next 3 Stories	Soft Story Issue
Roof	0.483	0.0483	0.0338	0.0386	--	No
8	0.441	0.0441	0.0309	0.0353	--	No
7	0.487	0.0487	0.0341	0.0390	--	No
6	0.478	0.0478	0.0334	0.0382	0.0470	No
5	0.398	0.0398	0.0278	0.0318	0.0469	No
4	0.422	0.0422	0.0295	0.0337	0.0454	No
3	0.299	0.0299	0.0209	0.0239	0.0432	No
2	0.280	0.0280	0.0196	0.0224	0.0371	No
1	0.116	0.0116	0.0081	0.0093	0.0333	No

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Lateral Connections & Detailing

Drift and Displacement Calculations for SCBF N-S Direction

Story	Height (Ft.)	hsx (ft.)	Story Displacement (in)	δxe (in)	δx (in)	Δa (in)	Final Results
Roof	10	10	3.236	0.494	2.257	2.400	Good
8	10	10	2.742	0.487	2.223	2.400	Good
7	10	10	2.255	0.441	2.016	2.400	Good
6	10	10	1.814	0.433	1.977	2.400	Good
5	10	10	1.381	0.364	1.663	2.400	Good
4	10	10	1.017	0.388	1.774	2.400	Good
3	10	10	0.629	0.275	1.256	2.400	Good
2	10	10	0.354	0.257	1.175	2.400	Good
1	10	10	0.097	0.097	0.441	2.400	Good

Drift and Displacement Calculations for SCBF E-W Direction

Story	Height (Ft.)	hsx (ft.)	Story Displacement (in)	δxe (in)	δx (in)	Δa (in)	Final Results
Roof	10	10	3.402	0.483	2.316	2.400	Good
8	10	10	2.919	0.441	2.115	2.400	Good
7	10	10	2.478	0.487	2.338	2.400	Good
6	10	10	1.991	0.478	2.291	2.400	Good
5	10	10	1.514	0.398	1.907	2.400	Good
4	10	10	1.116	0.422	2.022	2.400	Good
3	10	10	0.694	0.299	1.432	2.400	Good
2	10	10	0.396	0.280	1.341	2.400	Good
1	10	10	0.116	0.116	0.557	2.400	Good

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Lateral Connections & Detailing

Live Loads

Occupancy	Design Load	Code Required Loads	
		Load	Code
Corridors	100 psf	100 psf	ASCE 7
Offices	50 psf	50 psf	ASCE 7
Seminar Room	100 psf	40 psf	ASCE 7
Mechanical Room	125 psf	125 psf	ASCE 7
Partition	20 psf		
Roof	100 psf	100 psf	ASCE 7
Dormitory Rooms	40 psf	40 psf	ASCE 7
Lobby	100 psf	100 psf	ASCE 7
Stairs and exit ways	100 psf	100 psf	ASCE 7

Dead Loads

	Material	Design Weight
Roof Dead Load		
	Green Roof	50 psf wet
	Structural Members	15 psf
	Floor Slab	46 psf
	M/E/P	5 psf
	Ceiling Finishes	5 psf
	Total Dead Load	121 psf
	Material	Design Weight
Typ. Floor Dead Load		
	Structural Members	15 psf
	Floor Slab	46 psf
	M/E/P	5 psf
	Ceiling Finishes	5 psf
	Total Dead Load	71 psf