UNIVERSITY HEALTH BUILDING

LOCATED IN THE MID-ATLANTIC REGION

THESIS FINAL PRESENTATION

EVAN LANDIS || STRUCTURAL OPTION
ADVISOR || HEATHER SUSTERSIC

OUTLINE

Introduction
Structural Overview
Thesis Proposal
Lateral System Redesign
Lateral System Cost
Foundation Redesign
Foundation Cost/Schedule
Building Envelope
Conclusion

OUTLINE

INTRODUCTION

PROJECT INFO

Cost: $56 Million
Size: 161,000 SF
Floors: 7

STRUCTURAL OVERVIEW

FOUNDATION

- Spread footings
- Grade beam tie ins for basement retaining walls

FLOOR SLABS

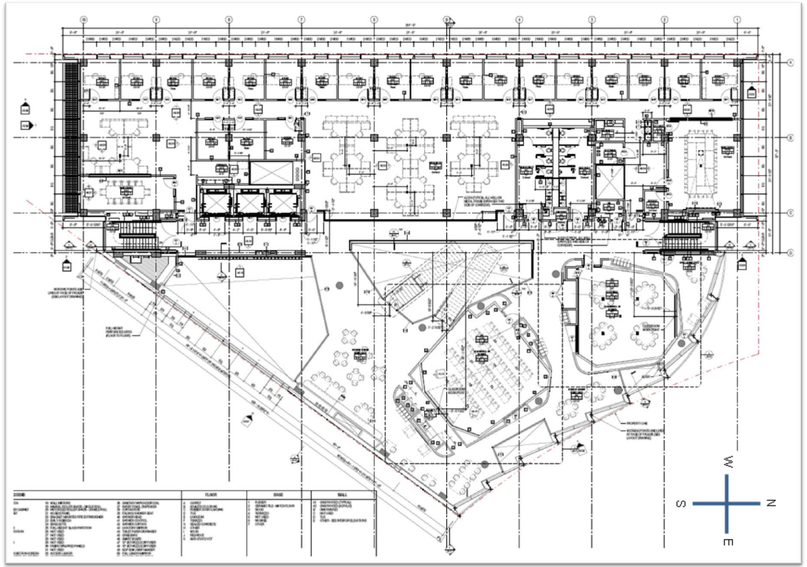
- Two-way post tensioned slabs
- f'c = 6-8ksi

LATERAL SYSTEM

- Concrete Moment Frames
- One Shear wall

ROOF SYSTEM

- Green roof on post tensioned slab
- White PVC membrane on post tensioned concrete slab



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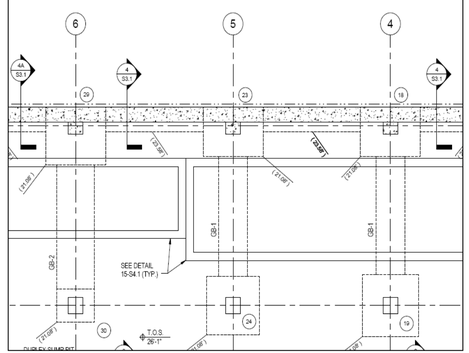

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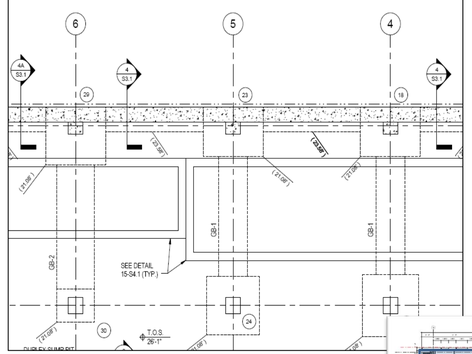

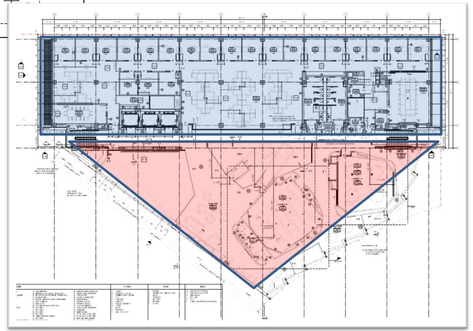

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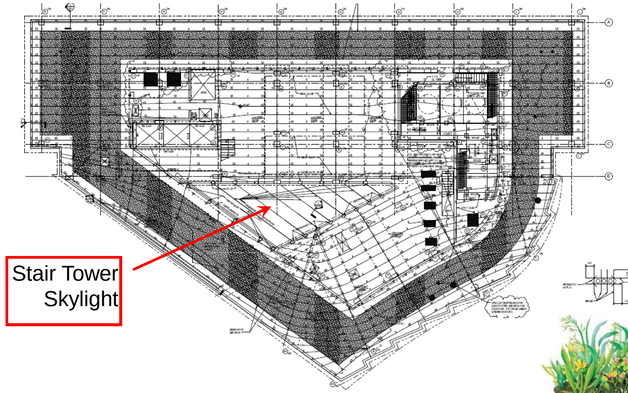

Image from usa.sarnafil.sika.com

OUTLINE

THESIS PROPOSAL

STRUCTURAL DEPTH

- Owners want to open a branch campus in Orlando, Florida

SCOPE

- Lateral System Analysis
  - Foundations check

COST/SCHEDULE ANALYSIS BREADTH

- To determine the cost associated with the changes to the lateral and foundation systems
- Determine the increase to the building schedule due to changes

BUILDING ENVELOPE ANALYSIS

- Determine the condensation point in a typical wall section
- Determine if the R-Value meets minimum standards for new location

MAE REQUIREMENTS

- AE 530 Computer Modeling of Building Structures
- AE 542 Building Enclosure Science and Design

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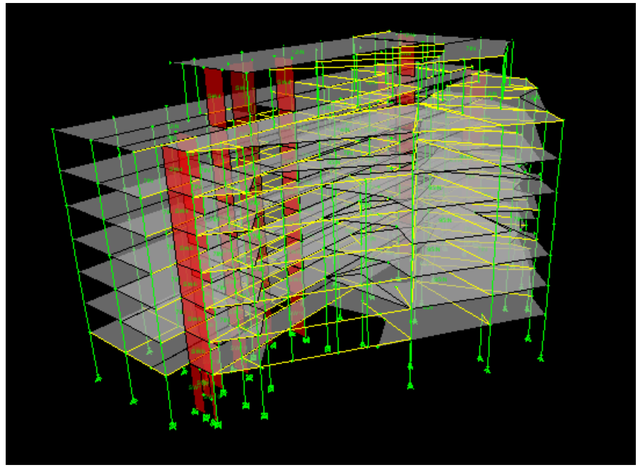
STRUCTURAL DEPTH

ETABS MODEL

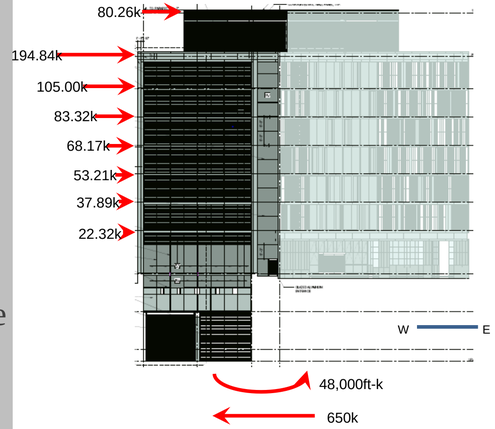
- All structural elements were modeled
- Modulus of Elasticity was halved to allow for the inelastic response of concrete members
- Live Loads and Superimposed Dead Loads were placed on the model
- Floor Slabs modeled as rigid diaphragms
- Shear walls modeled as membrane elements



OUTLINE

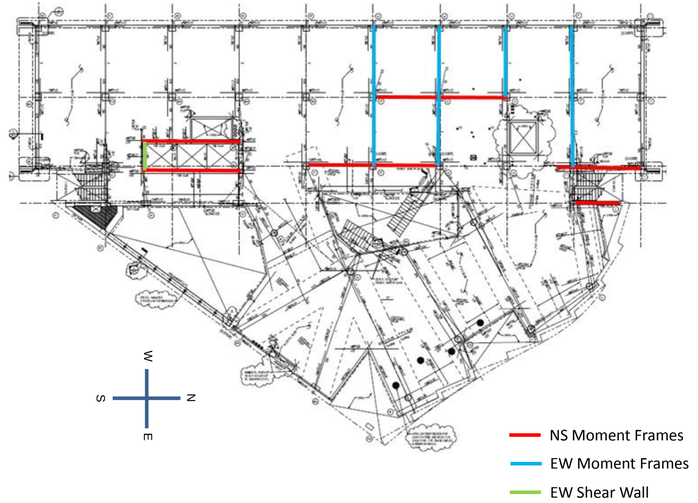
STRUCTURAL DEPTH

STORY FORCES



ORIGINAL LATERAL SYSTEM

- Designed for seismic loading
- Very few moment frames due to column discontinuities



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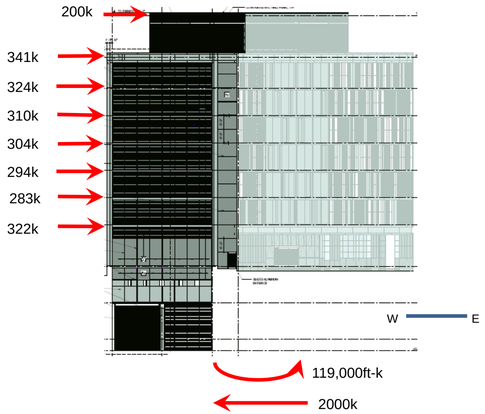
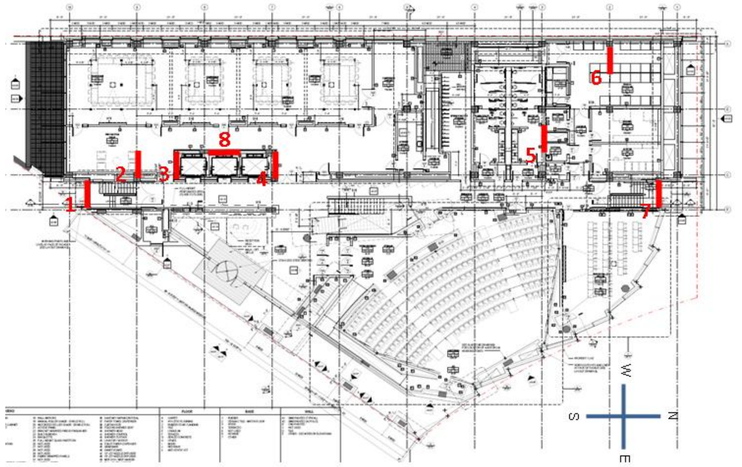


LATERAL SYSTEM ADDITIONS

- Designed for wind velocity of 145mph (Orlando Building Code)
- Addition of (7) 12” thick shear walls of varying lengths
- Alterations to existing shear wall
- h/400 = 3.3”



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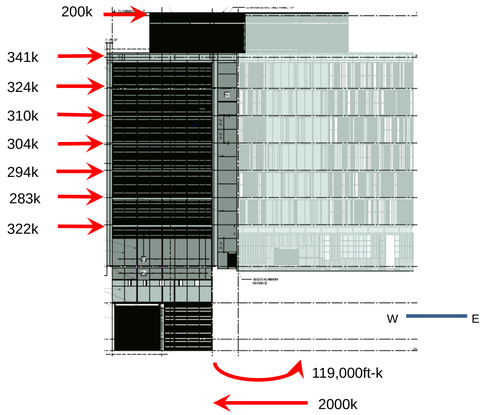

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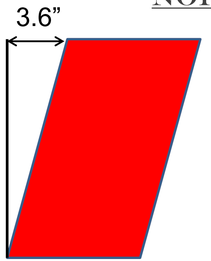
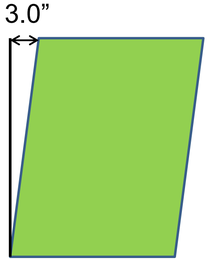
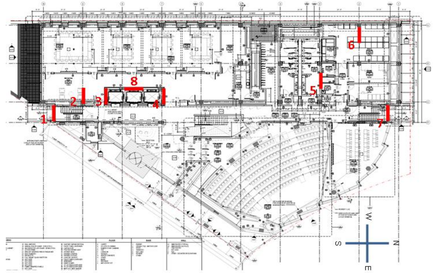
NORTH-SOUTH



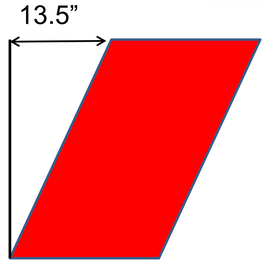
Original System



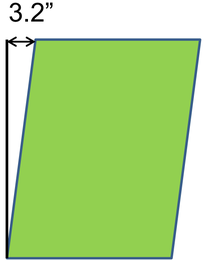
New System



EAST-WEST



Original System



New System

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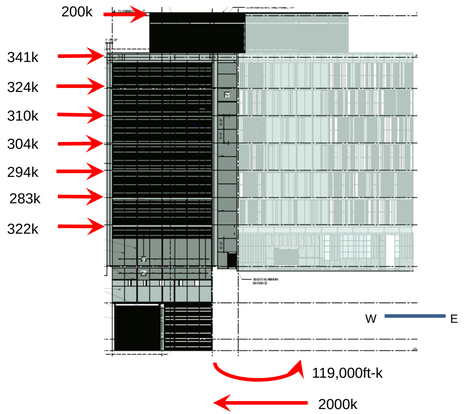
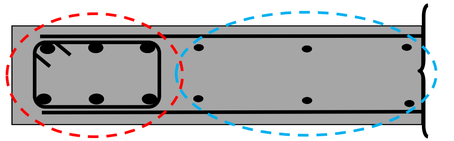
STORY FORCES

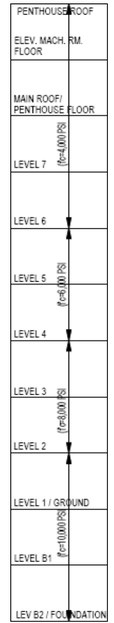


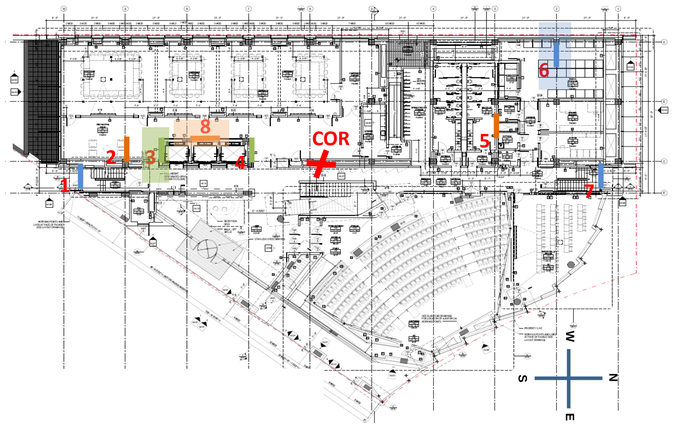
STRUCTURAL DEPTH

SHEAR WALL DESIGN

- Designed with boundary elements
- Walls of same length designed with same rebar configuration for ease of construction
- Typ. (6) or (8) #9's or #10's in boundary element
- #5's @ 12" Vertical
- #5's @ 12" Horizontal







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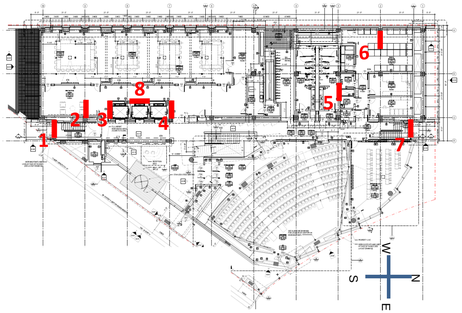
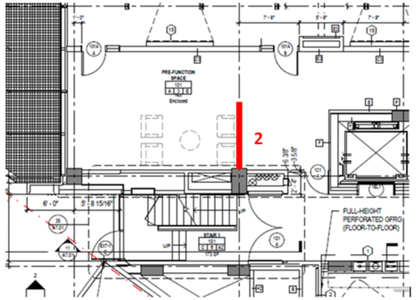
STRUCTURAL DEPTH



SHEAR WALL PLACEMENT

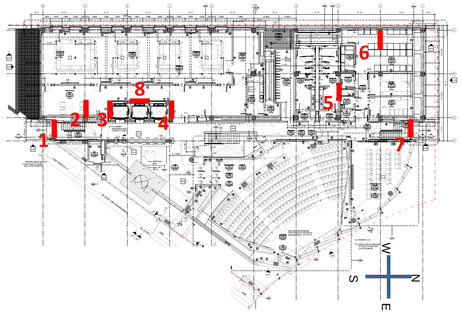
- Main goal was to not disrupt the architectural flow of the building
- Could not be avoided entirely



Pre-function Space

OUTLINE

STRUCTURAL DEPTH



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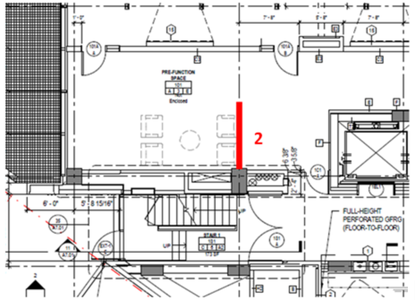
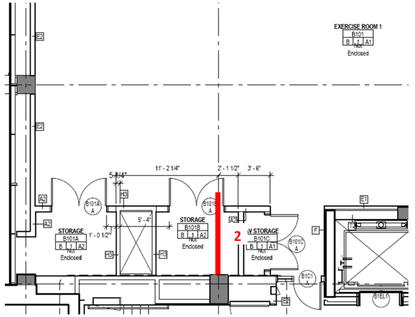


Pre-function Space

Exercise Room
(2) Storage Closets
AV Storage



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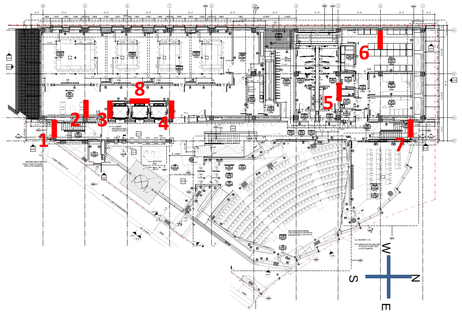

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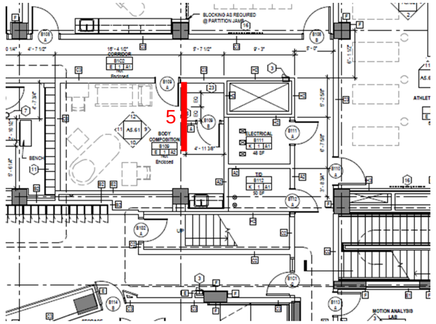
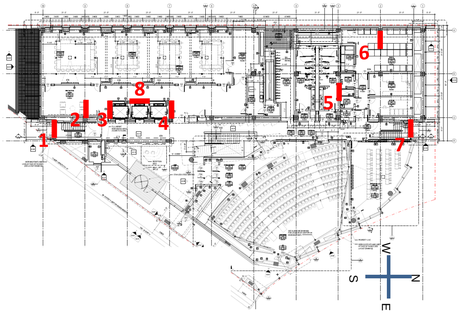


Body Composition Room

OUTLINE

STRUCTURAL DEPTH



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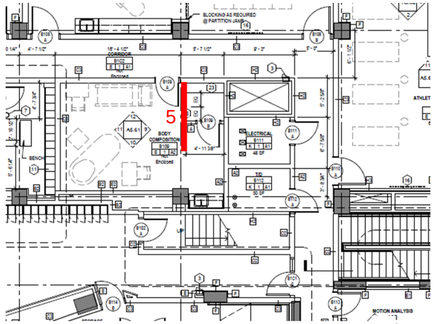
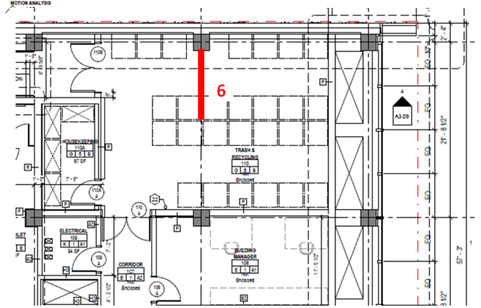


Body Composition Room

Trash and Recycling Room



OUTLINE

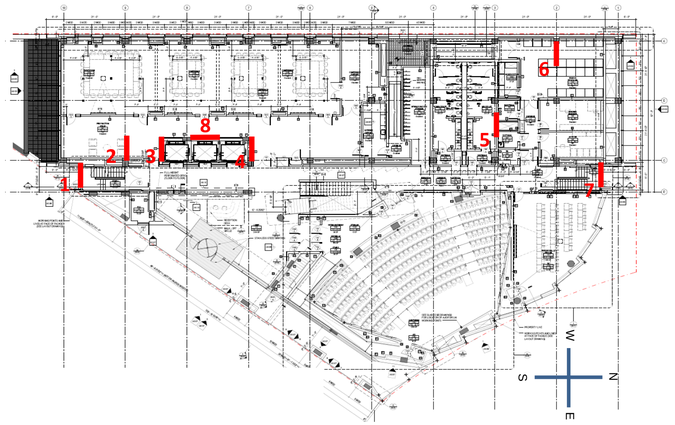
COST/SCHEDULE BREADTH

SHEAR WALL COST INCLUDES

- 4-10ksi concrete
- Rebar
- Formwork
- Pumping
- Placement
- Finishing

SHEAR WALL SCHEDULE: Negligible

Wall	Length (ft)	Thickness (ft)	Total
1,6,7	11	1	$ 51,005.72
4	8	1	$ 14,924
8,5	10	1	$ 37,308.76
2	10	1	$ 15,456
			$ 119,000



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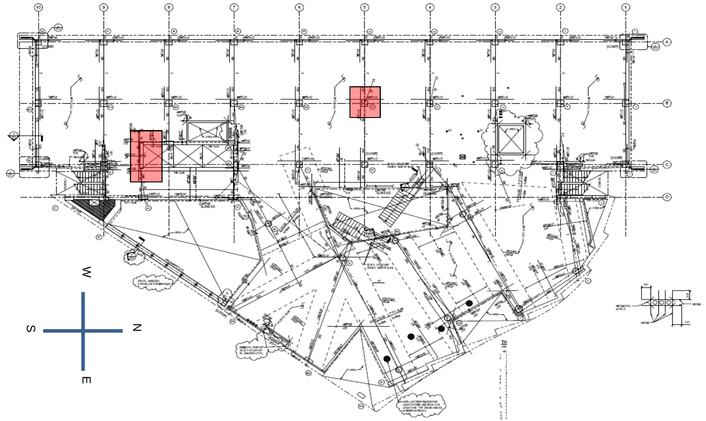
STRUCTURAL DEPTH

ORIGINAL FOUNDATION

- Spread footings
- Soil Bearing Capacity: 30ksf bedrock
- Typical sizes: 6x6, 5x4, 9x9
- f'c = 5ksi

GOALS

- Design new spread footings for single shear walls and typ. column
- To determine percent increase to size



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STRUCTURAL DEPTH

FOUNDATION DESIGN

- Trial 1: Spread footings on soil: 2-3ksf
  - Not suitable for loading
- Trial 2: Spread footings on structural fill: 8ksf
  - Typ. Column: 12x12
  - Typ. Shear Wall: no good
- Trial 3: 50ft Caissons: 20ksf bedrock

Caisson Foundation

	Shaft Dia. (ft)	Bell Dia. (ft)	Amount	Cap (ft)	Cap Reinforcement	Caisson Reinforcement	
						Verticle	Ties
Column	3.5	8.5	1	5x5	#4's @ 10" O.C. top and bottom each way	(7) #9's	#3's @ 18" from top to 10ft.
Shear Wall	3	7	2	5x13	#6's @ 10" O.C. top and bottom each way	(7) #8's	#3's @ 16" from top to 10.5ft.

Sandy Soil

Structural Fill

Bedrock

OUTLINE

COST/SCHEDULE BREADTH

FOUNDATION COST INCUDES

- 3ksi concrete caisson
- 5ksi concrete cap
- Casing and Pumping
- Excavation
- Mobilization
- Haul excess excavation
- Inspection
- Equipment

Proposed System		
Caissons	$	595,832
Caisson Caps	$	38,991
Original System		
Spread Footings	$	63,869
Cost Difference	**$**	**570,954**

FOUNDATION SCHEDULE

- 1 caisson per column
- 2 caissons per shear wall
- Original number of spread footings

Type	Amount	No. Completed per Day	Days Needed
Caisson	63	2	32
Spread Footing	48	5	10

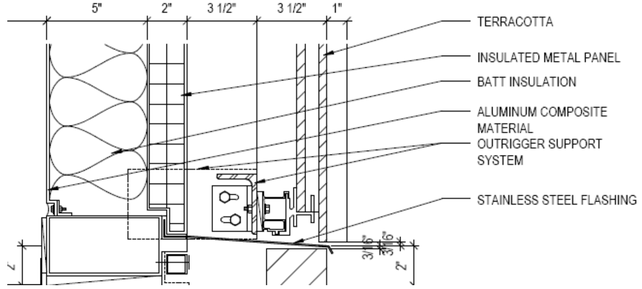
22 Days

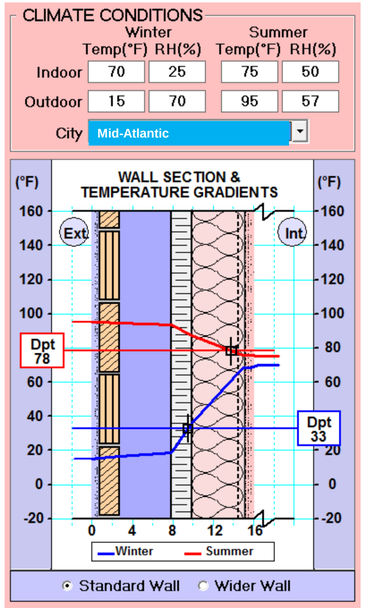
OUTLINE

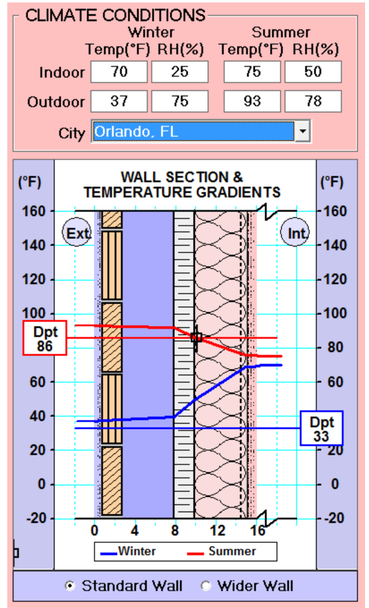
BUILDING ENVELOPE BREADTH

CONDENSATION ANALYSIS

- To determine if typical wall section will work in the humid Orlando Climate







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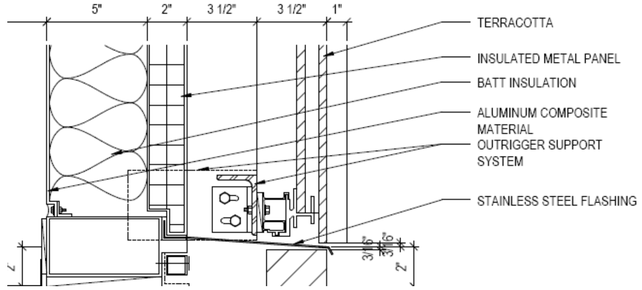
BUILDING ENVELOPE BREADTH

R-VALUE ANALYSIS

- ASHRAE 90.1 Energy Standard for Buildings
- R-Value does not include Terra Cotta



R-Values			
Location	Climate Zone	Required R-value (h*ft^2*F/BTU)	R-value of wall assembly (h*ft^2*F/BTU)
Mid-Atlantic	4	9.5	25.4
Orlando, Florida	2	5.7	25.4

OUTLINE

CONCLUSION

LATERAL SYSTEM
- 7 new shear walls
- 1 updated shear wall

FOUNDATION
- Change from spread footings to caissons

BUILDING ENVELOPE
- No changes necessary

COST

- Shear Walls	$119,000
- Foundations	+$571,000
	$690,000

QUESTIONS?

Special Thanks to the ones that made this possible:

PENNSTATE 1855

ae

WT WHITING-TURNER

PAYETTE

APPENDIX

Shear Wall Cost								
Wall	Floor	Story Height (ft)	Length (ft)	Thickness (ft)	f'c (ksi)	C.Y.	Cost/C.Y.	Total
1,6,7	7	13.5	11	1	4	5.50	$ 397	$ 2,182
	6	12	11	1	4	4.89	$ 363	$ 1,776
	5	12	11	1	6	4.89	$ 384	$ 1,879
	4	12	11	1	6	4.89	$ 384	$ 1,879
	3	12	11	1	8	4.89	$ 462	$ 2,260
	2	12	11	1	8	4.89	$ 462	$ 2,260
	1	18	11	1	10	7.33	$ 650	$ 4,765
2	7	13.5	10	1	4	5.00	$ 397	$ 1,984
	6	12	10	1	4	4.44	$ 363	$ 1,615
	5	12	10	1	6	4.44	$ 384	$ 1,708
	4	12	10	1	6	4.44	$ 384	$ 1,708
	3	12	10	1	8	4.44	$ 462	$ 2,055
	2	12	10	1	8	4.44	$ 462	$ 2,055
	1	18	10	1	10	6.67	$ 650	$ 4,332
4	8	18.5	8	1	4	5.48	$ 467	$ 2,558
	7	13.5	8	1	4	4.00	$ 397	$ 1,587
	6	12	8	1	4	3.56	$ 363	$ 1,292
	5	12	8	1	6	3.56	$ 384	$ 1,367
	4	12	8	1	6	3.56	$ 384	$ 1,367
	3	12	8	1	8	3.56	$ 462	$ 1,644
	2	12	8	1	8	3.56	$ 462	$ 1,644
	1	18	8	1	10	5.33	$ 650	$ 3,465
8,5	8	18.5	10	1	4	6.85	$ 467	$ 3,198
	7	13.5	10	1	4	5.00	$ 397	$ 1,984
	6	12	10	1	4	4.44	$ 363	$ 1,615
	5	12	10	1	6	4.44	$ 384	$ 1,708
	4	12	10	1	6	4.44	$ 384	$ 1,708
	3	12	10	1	8	4.44	$ 462	$ 2,055
	2	12	10	1	8	4.44	$ 462	$ 2,055
	1	18	10	1	10	6.67	$ 650	$ 4,332
							Total	$ 118,694

Shear Wall Reinforcing					
				Temperature/Shrinkage**	
Wall	Length (ft)	Boundary Element*	Shear	Vertical	Horizontal
1	11	(8) #9's	None	#5's @ 12"	#5's @ 12"
2	10	(8) #10's	None	#5's @ 12"	#5's @ 12"
3	8	(6) #9's	None	#5's @ 12"	#5's @ 12"
4	8	(6) #9's	None	#5's @ 12"	#5's @ 12"
5	10	(8) #10's	None	#5's @ 12"	#5's @ 12"
6	11	(8) #9's	None	#5's @ 12"	#5's @ 12"
7	11	(8) #9's	None	#5's @ 12"	#5's @ 12"
8	10	(8) #10's	None	#5's @ 12"	#5's @ 12"
		*Amount of rebar given per boundary element			
		**Walls 1 and 7 have special conditions @ ground level for door opening			

Sec. 13.3. - Ultimate design wind speeds.

(a) Pursuant to "Note 2," *Figure 1609A*, of the *Building* volume of the building code, the ultimate design wind speeds for Risk Category II buildings and other structures within the City is hereby interpolated as 135 miles per hour.

(b) Pursuant to "Note 2," *Figure 1609B*, of the *Building* volume of the building code, the ultimate design wind speeds for Risk Category III and IV buildings and other structures within the City is hereby interpolated as 145 miles per hour.

(c) Pursuant to "Note 2," *Figure 1609C*, of the *Building* volume of the building code, the ultimate design wind speeds for Risk Category I buildings and other structures within the City is hereby interpolated as 125 miles per hour.

Ord. No. 2012-10, § 1, 3-26-2012, Doc. #1203261201)

Orlando Florida Building Code

Layer	Generic Material	Thick.	R Val.
1	air film (ext), 3/4 in.	0.75	0.17
2	Terra Cotta blk., 2 in.	2.00	0.54
3	cavity, 5-1/2 in.	5.00	0.98
4	rigid ins.,(expand.), 2 in.	2.00	7.90
5	batt ins., 5 in.	5.00	15.24
6	steel (V) liner 3/4 in.	0.72	0.01
7	air film (int), 3/4 in.	0.75	0.64
8			
9			
10			
11			
12			
	Total or (Layer 0)		

APPENDIX

West Wall

Story	Story height	Elevation	Trib. Height (ft.)	Trib. Length (ft)	K_z	q_z	q_h	P_w(psf)	P_l(psf)	Trib. Area	Total Story Force (kip)	Overturning Moment (ft-k)
1	0	0.0	9.00	200	0	0	0	0	-52	1800	93.60	0.00
2	18	18.0	15.00	200	0.6	31.57	31.5678	38.83	-52	3000	272.49	4904.73
3	12	30.0	12.00	200	0.7	36.83	36.8291	45.30	-52	2400	233.52	7005.58
4	12	42.0	12.00	200	0.77	40.51	40.512	49.83	-52	2400	244.39	10264.44
5	12	54.0	12.00	200	0.83	43.67	43.6688	53.71	-52	2400	253.71	13700.35
6	12	66.0	12.00	200	0.87	45.77	45.7733	56.30	-52	2400	259.92	17154.90
7	12	78.0	12.75	200	0.92	48.40	48.4039	59.54	-52	2550	284.42	22184.67
Penthouse	13.5	91.5	16.00	140	0.96	50.51	50.5084	62.13	-52	2553	291.31	26654.41
T.O.C. Roof	18.5	110.0	9.25	140	1.02	53.67	53.6652	66.01	-52	1295	152.82	16810.27
									∑		2,086	118,679

Perimeters	
I=	1.15
G=	0.85
C_p Windward=	0.80
C_p Leeward=	-0.50
K_{zt}=	1.00
K_d=	0.85
Velocity=	145.00
GC_{pi}=	0.55

South Wall

Story	Story height	Height	Trib. Height (ft.)	Trib. Length (ft)	K_z	q_z	q_h	P_w(psf)	P_l(psf)	Trib. Area	Total Story Force (kip)	Overturning Moment (ft-k)
1	0	0	9.00	130	0	0	53.67	29.51587	-43	1170	85.08	0.00
2	18	18	15.00	130	0.6	31.57	53.67	50.98196	-43	1950	183.26	3298.77
3	12	30	12.00	130	0.7	36.83	53.67	54.55964	-43	1560	152.19	4565.79
4	12	42	12.00	130	0.77	40.51	53.67	57.06402	-43	1560	156.10	6556.19
5	12	54	12.00	130	0.83	43.67	53.67	59.21063	-43	1560	159.45	8610.22
6	12	66	12.00	130	0.87	45.77	53.67	60.6417	-43	1560	161.68	10670.95
7	12	78	12.75	130	0.92	48.40	53.67	62.43054	-43	1657.5	174.75	13630.59
Penthouse	13.5	91	16.00	90	0.96	50.51	53.67	63.86161	-43	1710	182.73	16628.74
T.O.C. Roof	18.5	110	9.25	90	1.02	53.67	53.67	66.00822	-43	832.5	90.75	9982.43
									∑		1,346	73,944

Perimeters	
I=	1.15
G=	0.85
C_p Windward=	0.80
C_p Leeward=	-0.30
K_{zt}=	1.00
K_d=	0.85
Velocity=	145.00
GC_{pi}=	0.55

Original Lateral System

Wind Drift: North-South

Floor	Story Height (ft)	Story Drift Ratio X (in/in)	Story Drift X (in/in)	Story Drift Ratio Y (in/in)	Story Drift Y (in)	Total Drift X	Total Drift Y	Allowable Total Drift	Acceptable X	Acceptable Y
8	18.5	0.002661	0.590742	0.000941	0.20890	3.62898	2.05345	3.30	No	Yes
7	13.5	0.002575	0.41715	0.001531	0.24802	3.038238	1.84455	2.75	No	Yes
6	12	0.003081	0.443664	0.001914	0.27562	2.621088	1.596528	2.34	No	Yes
5	12	0.003426	0.493344	0.002184	0.31450	2.177424	1.320912	1.98	No	Yes
4	12	0.003522	0.507168	0.002205	0.31752	1.68408	1.006416	1.62	No	Yes
3	12	0.003359	0.483696	0.002049	0.29506	1.176912	0.688896	1.26	Yes	Yes
2	12	0.002825	0.4068	0.001595	0.22968	0.693216	0.39384	0.90	Yes	Yes
1	18	0.001326	0.286416	0.000760	0.16416	0.286416	0.16416	0.54	Yes	Yes

Wind Drift: East-West

Floor	Story Height (ft)	Story Drift Ratio X (in/in)	Story Drift X (in)	Story Drift Ratio Y (in/in)	Story Drift Y (in)	Total Drift X	Total Drift Y	Allowable Total Drift	Acceptable X	Acceptable y
8	18.5	0.000298	0.066156	0.005853	1.29937	0.088	13.55312	3.30	Yes	No
7	13.5	0.001152	0.001152	0.007756	1.25647	0.022	12.25375	2.75	Yes	No
6	12	0.002769	0.002769	0.01137	1.63728	0.020	10.99728	2.34	Yes	No
5	12	0.003811	0.003811	0.01441	2.07504	0.018	9.36000	1.98	Yes	No
4	12	0.004416	0.004416	0.015385	2.21544	0.014	7.28496	1.62	Yes	No
3	12	0.004302	0.004302	0.014637	2.10773	0.009	5.06952	1.26	Yes	No
2	12	0.003408	0.003408	0.011622	1.67357	0.005	2.96179	0.90	Yes	No
1	18	0.001758	0.001758	0.005964	1.28822	0.002	1.28822	0.54	Yes	No

New Lateral System

Wind Drift: North-South

Floor	Story Height (ft)	Story Drift Ratio X (in/in)	Story Drift X (in)	Story Drift Ratio Y (in/in)	Story Drift Y (in)	Total Drift X	Total Drift Y	Allowable Total Drift	Acceptable X	Acceptable y
8	18.5	0.002492	0.553224	0.000596	0.13231	3.06885	1.51646	3.30	Yes	Yes
7	13.5	0.002553	0.413586	0.000629	0.10190	2.515626	1.384146	2.75	Yes	Yes
6	12	0.002766	0.398304	0.006390	0.92016	2.10204	1.282248	2.34	Yes	Yes
5	12	0.003032	0.436608	0.000621	0.08942	1.703736	0.362088	1.98	Yes	Yes
4	12	0.003007	0.433008	0.000604	0.08698	1.267128	0.272664	1.62	Yes	Yes
3	12	0.003063	0.441072	0.000559	0.08050	0.83412	0.185688	1.26	Yes	Yes
2	12	0.002443	0.351792	0.000444	0.06394	0.393048	0.105192	0.90	Yes	Yes
1	18	0.001159	0.250344	0.000191	0.04126	0.04126	0.041256	0.54	Yes	Yes

Wind Drift: East-West

Floor	Story Height (ft)	Story Drift Ratio X (in/in)	Story Drift X (in)	Story Drift Ratio Y (in/in)	Story Drift Y (in)	Total Drift X	Total Drift Y	Allowable Total Drift	Acceptable X	Acceptable y
8	18.5	0.000174	0.038628	0.00313	0.69486	0.219	3.24650	3.30	Yes	Yes
7	13.5	0.000169	0.027378	0.00307	0.49734	0.180	2.55164	2.75	Yes	Yes
6	12	0.000337	0.048528	0.003043	0.43819	0.153	2.05430	2.34	Yes	Yes
5	12	0.000134	0.019296	0.003038	0.43747	0.104	1.61611	1.98	Yes	Yes
4	12	0.000174	0.025056	0.002455	0.35352	0.085	1.17864	1.62	Yes	Yes
3	12	0.000194	0.027936	0.002557	0.36821	0.060	0.82512	1.26	Yes	Yes
2	12	0.000134	0.019296	0.00197	0.28368	0.032	0.45691	0.90	Yes	Yes
1	18	0.000059	0.012744	0.000802	0.17323	0.013	0.17323	0.54	Yes	Yes

APPENDIX

Wall 1 Level 1					
F'c	10	ksi	t=	12	in
Lw=	132	in	Mn=	34681	k*in
Nu=	397.5	k	Vu=	161	k
d=	123.96	in			
(#)	No. Bar	Area bar	Grade		
6	6	0.44	60		
Flexure					
T=	158.4				
a=	5.45	<	46.485		
.9M=	39919.89	>	34681	k*in	

Wall 1 Level 2					
F'c	8	ksi	t=	12	in
Lw=	132	in	Mn=	22109	k*in
Nu=	204	k	Vu=	135	k
d=	123.96	in			
(#)	No. Bar	Area bar	Grade		
6	6	0.44	60		
Flexure					
T=	158.4				
a=	4.441176	<	46.485		
.9M=	29065.07	>	22109	k*in	
Shear					
Vc=	486.9515				
	356.093				
.75Vc=	267.0697				
Vs=	-176.093				
Areq=	-0.28411				
rho=	-0.00197	<	0.0025		

Wall 1 Level 4					
F'c	6	ksi	t=	12	in
Lw=	132	in	Mn=	12581	k*in
Nu=	62	k	Vu=	105	k
d=	123.96	in			
(#)	No. Bar	Area bar	Grade		
6	6	0.44	60		
Flexure					
T=	158.4				
a=	3.601307	<	46.485		
.9M=	20997.36	>	12581	k*in	
Shear					
Vc=	394.7912				
	450.9477				
.75Vc=	296.0934				
Vs=	-254.791				
Areq=	-0.41109				
rho=	-0.00285	<	0.0025		

Wall 1 Level 6					
F'c	4	ksi	t=	12	in
Lw=	132	in	Mn=	5850	k*in
Nu=	16	k	Vu=	61	k
d=	123.96	in			
(#)	No. Bar	Area bar	Grade		
6	6	0.44	60		
Flexure					
T=	158.4				
a=	4.27451	<	46.485		
.9M=	18286.67	>	5850	k*in	
Shear					
Vc=	314.2171				
	588.85				
.75Vc=	235.6629				
Vs=	-232.884				
Areq=	-0.37574				
rho=	-0.00261	<	0.0025