1776 WILSON BOULEVARD

ARLINGTON VIRGINIA

1776 WILSON BOULEVARD SKANSKA

Penn State University
Senior Thesis 2012

Faculty Advisor: Thomas Boothby

Joshua Urban
Structural Option

PRESENTATION OVERVIEW

BUILDING INTRODUCTION AND EXISTING INFORMATION

PROPOSAL OVERVIEW

STRUCTURAL DEPTH

CONSTRUCTION MANAGEMENT BREADTH SUMMARY

SUSTAINABILITY BREADTH

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BUILDING STATISTICS

- LOCATED IN ARLINGTON COUNTY, VIRGINIA
- CLASS A OFFICE WITH RETAIL
- 249,000 SF
- 5 STORIES WITH 3 ½ BELOW GRADE PARKING
- $63.5 MILLION CONTRACT VALUE
- DESIGN-BID-BOND
- C-O-2.5 ZONING DISTRICT
- SEPARATE MIXED USE

TCE Associates, Inc. · RTKL · SDK · GIRARD ENGINEERING · C.W. KLING & ASSOCIATES, INC. · SKANSKA

INTRODUCTION

INTRO · EXIST · DEPTH · CM · SUST

ARCHITECTURE AND SUSTAINABILITY

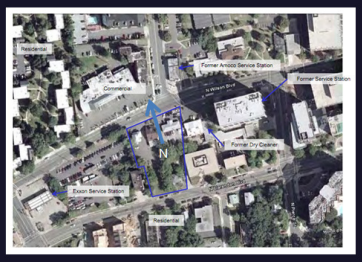
- RETAIL SPACE ON GROUND FLOOR WITH TENNANT MEZZANINES
- 4 FLOORS OF OPEN OFFICE SPACE
- PRECAST CONCRETE PANELS
- GENEROUS GLAZING AND CURTAIN WALLS
- REDUCED TRAFFIC IMPACT
- PUBLIC PARK AREA AND ROOF TERRACE
- BROWNFIELD REDEVELOPMENT
- GREEN ROOF AND SOLAR PV PANELS

INTRODUCTION

INTRO · EXIST · DEPTH · CM · SUST

SITE CONDITIONS

- ASPHALT, GRAVEL, AND TOPSOIL GROUND COVER
- BELOW GROUND STRATA
- HIGH GROUNDWATER FLOW
- 45,500 SF FOOTPRINT AREA
- ONE AND TWO STORY BUILDINGS



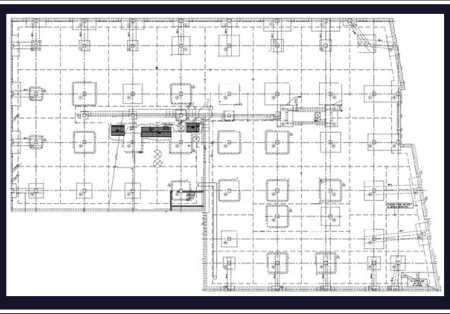
Stratum	Name	Description
I	Fill/Possible Fill	17-36 feet below site grades consisting of various amounts of sand, gravel, and clay
II	Natural Alluvial/Marine Solids	28-52 feet below site grades and under stratum 1, this stratum consists of poorly graded sand, clayey sand, and low plasticity clay with varying gravel content
III	Residual Soils/Weathered Rock	Below stratum 2 and consists of Micaceous silty sand with rock fragments.

EXISTING STRUCTURE

INTRO EXIST DEPTH CM SUST

FOUNDATION

- SHALLOW FOUNDATION
- BEARING CAPACITY OF 10,000 PSF
- SLAB ON GRADE AND FOOTINGS



EXISTING STRUCTURE

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- SLAB ON GRADE AND FOOTINGS

FLOOR SYSTEM

- HIGH STRENGTH POST TENSIONED CONCRETE
- FLAT SLAB WITH DROPS
- 30' X 30' AND 30' X 45' BAYS

COLUMNS

- GROUND FLOOR 24" X 24" COLUMNS
- 22" X 22" TYPICAL COLUMNS ABOVE
- 5 TO 8 KSI CONCRETE STRENGTH
- #9 TO # 11 REINFORCEMENT

EXISTING STRUCTURE

INTRO EXIST DEPTH CM SUST

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- FLAT SLAB WITH DROPS
- 30' X 30' AND 30' X 45' BAYS

ROOF

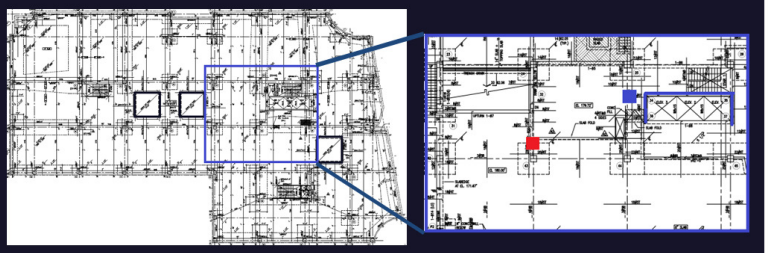
- LOWER ROOF TERRACE LIVE LOAD OF 100 PSF
- 25-26 PSF FOR GREEN ROOF
- SOLAR PANELS ADD 6.6 – 8 PSF TO DEAD LOAD
- ROOF COVERAGE IS VEGETATION, ROOF PAVERS, OR WEARING SLAB
- 8 TO 10 INCHES THICK

EXISTING STRUCTURE

INTRO EXIST DEPTH CM SUST

LATERAL SYSTEM

- ❖CONCRETE MOMENT FRAMES AND SHEAR WALLS
- ❖LOWEST R VALUE USED FOR DUAL SYSTEM
- ❖SLABS SERVE AS BEAMS
- ❖EACH COLUMN PARTICIPATES IN RESISTANCE
- ❖10" AND 12" SHEAR WALLS
- ❖TORSION AID

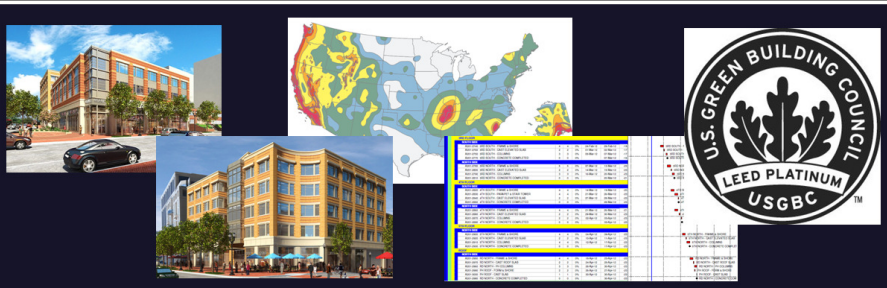


EXISTING STRUCTURE

INTRO EXIST DEPTH CM SUST

PROPOSAL

- ❖EFFICIENTLY DESIGNED
- ❖LOCATION CHANGE
- ❖REDESIGN FOR NEW SEISMIC LOADS
- ❖CONSTRUCTION MANAGEMENT
- ❖SUSTAINABILITY



NEW LOCATION

- ❖CENTRAL DISTRICT OAKLAND
- ❖LEED RELATED SITE BENEFITS
- ❖REDEVELOPMENT

NEW SEISMIC LOADS

STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

SEISMIC DESIGN CONSIDERATIONS

- ❖SEISMIC DESIGN CATEGORY D
- ❖SEISMIC PROVISIONS AISC 341-05

- ❖SPECIAL MOMENT FRAMES REQUIRED
- ❖REDUNCANCY FACTOR = 1.3
- ❖(1.2 + 0.2Sds)D + ρQe + L + 0.2S
  (0.9 – 0.2Sds)D + ρQe + 1.6H
- ❖ALLOWABLE STORY DRIFT = 0.02hsx
- ❖EQUIVALENT LATERAL FORCE ANALYSIS PERMITTED

Coefficients and Factors	Type	R	Overstrength	Deflection Amplification
Steel Structure	Special Concentrically Braced Frames	6	2	5
Concrete Structure	Special Reinforced Concrete Shear Walls	7	2 1/2	5.5

- ❖SLENDERNESS : Kl/r ≤ 4√E/Fy
- ❖WIDTH/THICKNESS RATIO: b/t ≤ 0.30√E/Fy
- ❖NO SHEAR STUDS IN PROTECTED ZONES

STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

CONCRETE REDESIGN

- F'c = 6000 PSI
- Fy = 60 KSI
- Fpu = 270,000 PSI
- 7 WIRE STRANDS ½" DIAMETER
- 60% LOAD BALANCE OF SELF WEIGHT

Tendon Locations	
Ext. Support	4"
Int. Support	7"
Int. Span Bottom	1.25"
End Span Bottom	1.75"

wb/wdl < 100%	96%	
Dead Load Moments	310 ft-k	at support
	248 ft-k	at mid span
Live Load Moments	202.5 ft-k	at support
	162 ft-k	at mid span
Total Balancing Moments	194 ft-k	at support
	155.5 ft-k	at mid span
Ultimate Strength	664 ft-k	at support
	573 ft-k	at mid span

Shear Strength	
Wide Beam Action	84.5 k
Two Way Action	235 k
Reinforcement Summary	
At supports	(10) #9 top interior
	(11) #4 top exterior
Midspan	#5 @ 12" oc bottom

Designed As	At Support Exterior
Hand	(11)#4 bars
RAM	(10)#4 bars
	At Support Interior
Hand	(10)#9 bars
RAM	(14)#9 bars
	Midspan Bottom
Hand	#5 @ 12"
RAM	#5 @ 15"

STRUCTURAL DEPTH

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CONCRETE REDESIGN

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- Fy = 60 KSI
- Fpu = 270,000 PSI
- 7 WIRE STRANDS ½" DIAMETER
- 60% LOAD BALANCE OF SELF WEIGHT

- INCREASE IN MEMBER SIZES
- INCREASE IN EDGE REINFORCEMENT
- INCREASE IN COLUMN/SLAB CONNECTION REINFORCEMENT
- COMPLEX DETAILING

STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

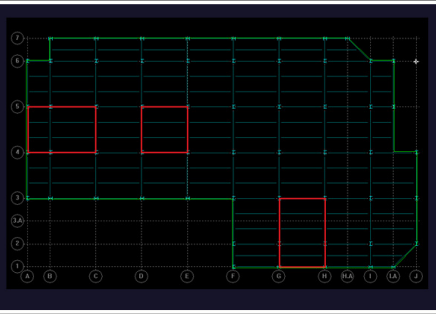
COMPOSITE STEEL PRO/CON

- LOWER WEIGHT
- DECREASED CONSTRUCTION TIME

- ADDITIONAL FIREPROOFING
- VIBRATION ISSUES
- BELOW GRADE PARKING

GRAVITY SYSTEM

- FRAMING PLANS
- HAND CALCULATIONS
- RAM STRUCTURAL SYSTEM MODEL



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STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

RAM STRUCTURAL SYSTEM

- HAND CALCULATION RESULTS USED TO ASSIGN SIZES
- CRITERIA SET FOR BEAM/ COLUMN CHECKS AND BEAM DEFLECTION
- ECONOMIZE LAYOUTS

Beam Design and Check Criteria	Column Design and Check Criteria
AISC 360-05 LRFD	AISC 360-05 LRFD for columns and base plates
Deck perpendicular to composite beam braces the flange	Trial groups of W14, W12, and W10 used
Camber included in design if necessary	Deck braces the column
Max stud spacing follows code Stud Placement: e mid-ht. < 2"	

Beam Deflection Criteria	
Composite Unshored	Live Load = L/360 Superimposed = L/240 Total = L/240
Composite Shored	Live Load = L/360 Total = L/240
Noncomposite	Live Load = L/360 Total = L/240

STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

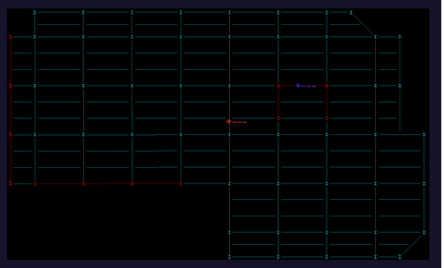
MOMENT FRAME LAYOUTS

CONSIDERATIONS

- LIMIT DRIFT
- AVOID P-DELTA INSTABILITIES
- MINIMIZE EFFECTS DUE TO TORSION
- MINIMIZE ARCHITECTURAL IMPACTS

1ST LAYOUT

- BRACED FRAMES AROUND ELEVATOR CORE
- PERIMETER MOMENT FRAMES
- LARGE TORSION EFFECTS



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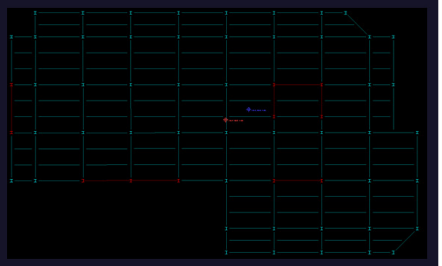
2ND LAYOUT

- BRACE PERIMETER FRAMES
- UPLIFT ISSUES AT CORNERS
- ARCHITECTURAL IMPACTS



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CONSIDERATIONS

- LIMIT DRIFT
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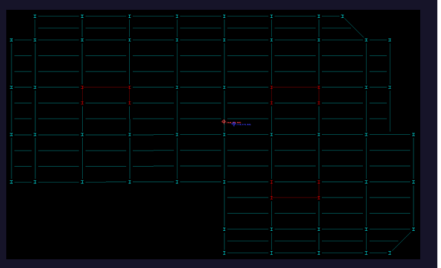
- MINIMIZE ARCHITECTURAL IMPACTS

3rd LAYOUT

- THREE INTERIOR BRACED CORES
- MINIMAL ARCHITECTURAL IMPACT
- MINIMAL EFFECT DUE TO TORSION

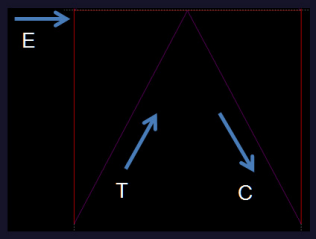


STRUCTURAL DEPTH

INTRO EXIST DEPTH CM SUST

HAND CALCULATIONS

Brace Design Data			
	1st Floor	2nd-4th Floor	5th Floor
Height (ft)	28	13.33	14.67
L Beam (ft)	30	30	30
L Brace (ft)	32	20	21
Angle (degrees)	28	48.6	45.6



Load Combinations
(1.2 + 0.2Sds)D + ρPqe + 0.5Pl
(0.9 + 0.2Sds)D - ρPqe

Brace Forces and Design	Ground Floor Braced Frames		
Compression	556.3 k		
Tension	538.8 k		
W Shape Selected	W14x120		

Brace Checks		
Slenderness	61.54<96.33	OK
Width/Thickness	7.8<8.5	OK

STRUCTURAL DEPTH

CONCLUSION

- LIMIT DRIFT
- AVOID P-DELTA INSTABILITIES
- MINIMIZE EFFECTS DUE TO TORSION
- MINIMIZE ARCHITECTURAL IMPACTS

Level	Story Height	0.02Hsx	Drift
Roof	14.67'	3.52	1.1
5th	13.33'	3.2	0.9
4th	13.33'	3.2	0.7
3rd	13.33'	3.2	0.65
2nd	28'	6.7	0.75

Brace Checks		
Slenderness	61.54<96.33	OK
Width/Thickness	7.8<8.5	OK

Stiffness Equations			
2 Diagonals	2cos^2(theta)(AE/L)		
1Diagonal	cos^2(theta)(AE/L)		
Center Of Rigidity			
	Hand Calculation	RAM Value	Difference
X-Direction	140 ft	141.07 ft	0.76%
Y-Direction	81.67 ft	81.78 ft	0.13%

STRUCTURAL DEPTH

OVERVIEW

- DON'T EXTEND SCHEDULE
- COMPARE COSTS AND DURATIONS
- DEVELOP CRITICAL PATHS

CONCRETE SCHEDULE

- FOLLOWS FORMAT OF ORIGINAL SCHEDULE
- UPDATED DURATIONS BASED ON INCREASE IN MATERIALS
- SUPERSTRUCTURE SCHEDULE EXTENDED 4 DAYS
- $1.7 MILLION INCREASE IN COST

STEEL SCHEDULE

- TWO CRANES, KEEP NORTH AND SOUTH ZONES
- TAKEOFFS PERFORMED BY HAND ON TYPICAL BAYS
- SUPERSTRUCTURE SCHEDULE SHORTENED BY 10 DAYS
- $625,000 INCREASE IN COST

CM BREADTH

OVERVIEW

- MAINTAIN LEED PLATINUM RATING
- PRIORITY LIST
- NEW SITE
- ENERGY PERFORMANCE
- HVAC LOADS

Priority	Category	Tasks
1	Sustainable Sites	Research new location choices Site type Local amenities Minimize traffic impact Heat island effects
2	Energy and Atmosphere	Green roof performance PV Solar Panel performance
3	Indoor Environmental Quality	Heating and cooling loads

SUSTAINABLE BREADTH

NEW SITE LOCATION

- ❖CENTRAL DISTRICT OAKLAND
- ❖BROWNFIELD OPPORTUNITIES
- ❖REDUCE TRAFFIC IMPACT
- ❖HEAT ISLAND

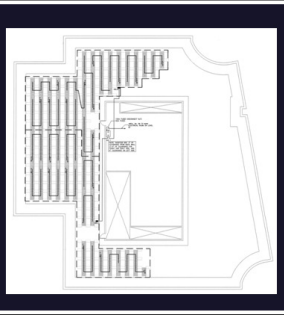
	Richmond Virginia	San Francisco California
Energy Savings Compared to White Roof	$863	-$160
Energy Savings Compared to Dark Roof	$1409	$957
Summer Peak Daily Average Sensible Heat Flux	-53.3 W/m^2	132.4 W/m^2
Summer Peak Daily Average Latent Heat Flux	124.4 W/m^2	0.2 W/m^2

SUSTAINABLE BREADTH

INTRO EXIST DEPTH CM SUST

SOLAR PANEL ANALYSIS

- ❖176 PANELS
- ❖2 COMBINER BOXES
- ❖8 PER STRING, 22 STRINGS
- ❖TOTAL SYSTEM SIZE OF 38.72KW



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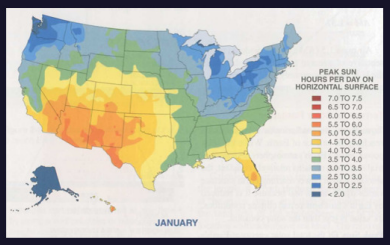
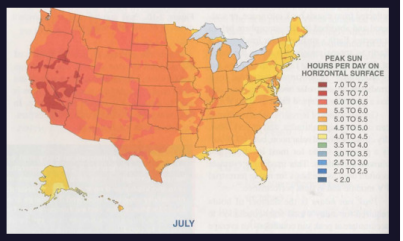
- ❖PEAK SUN HOURS DETERMINED
- ❖20% ASSUMED LOSSES TO AC





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- ❖HAND CALCS VS PV WATTS

Peak Sun Hours	Winter	Summer	Fall/Spring
Oakland	3.75	6.25	5
Arlington	3.25	5	4.12

Location	Hand Calc Value (kW-hr/year)	PV Watts Result (kW-hr/year)	% Difference
San Francisco	54,429	53,180	2.29%
Sterling	44,876	44,954	0.17%

SUSTAINABLE BREADTH

INTRO EXIST DEPTH CM SUST

SOLAR PANEL ANALYSIS

CONSIDERATIONS

- ITC GRANT
- ANNUAL UTILITY RATE INCREASES
- OPERATION AND MAINTENANCE
- METER AND INVERTER REPLACEMENTS
- PRODUCTION DECREASES

	Utility Rates	Annual Increase	Production Decrease
Oakland	12.5 cents/kW-hr	5%	0.70%
Arlington	8.0 cents/kW-hr	6.70%	0.70%

Costs		
Installation	$166,000	After ITC Grant
O&M	2%	Annual Increase
Meters	$2,500	Every 5 years
Inverters	$7,000	Every 10 years

Payback Period	
Oakland	18 Years
Arlington	30 Years

SUSTAINABLE BREADTH

INTRO EXIST DEPTH CM SUST

SOLAR PANEL ANALYSIS

GREEN ROOF INTEGRATION

- SOLAR PANELS INSTALLED OVER EXTENSIVE GREEN ROOF
- PANELS SHADE VEGETATION
- GREEN ROOF COOLS SOLAR PANELS
- UP TO 6% MORE EFFICIENT

Panel Area	1.26 m^2
100%	1260 W
Efficiency	17.50%

New Efficiency	20.50%
Useful Energy	258.3 W
System Size	45.5 kW

- CHECK EXISTING EFFICIENCY
- USE 3% EFFICIENCY INCREASE
- CALCULATE NEW SYSTEM SIZE
- INCLUDE GREEN ROOF ADDITION IN COST

PAYBACK PERIOD : 23 YEARS

31 YEARS TO PROVIDE COST SAVINGS OVER NON INTEGRATED SYSTEM

SUSTAINABLE BREADTH

INTRO EXIST DEPTH CM SUST

HEATING AND COOLING LOADS

- LOADS CALCULATED FOR SOUTH FACING OFFICE
- FOLLOWED ASHRAE HANDBOOK FUNDAMENTALS (2009)
- EXISTING ARLINGTON LOADS
- COMPARISONS

Cooling Loads							
Oakland	Walls	Windows	Lights	People	Misc.		Total
	127	1242.44	614	450	1408		3841
Arlington							
							5916

Heating Loads	
Oakland	Total
	4384
Arlington	
	4706

SIMPLIFYING ASSUMPTIONS

- STEADY STATE CONDITIONS
- SINGLE OUTSIDE TEMPERATURE
- NO HEAT GAIN FROM SOLAR OR INTERNAL SOURCES

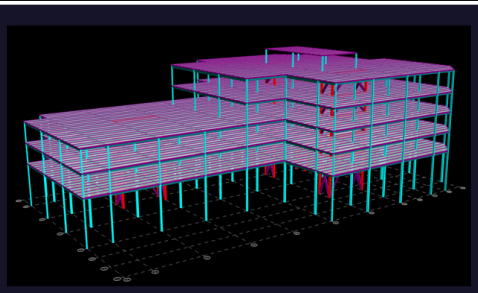
SUSTAINABLE BREADTH

INTRO EXIST DEPTH CM SUST

CONCLUSIONS

STRUCTURAL DEPTH

- CONCRETE STRUCTURE : INCREASED WEIGHT AND REINFORCEMENT
- STEEL REDESIGN : 3 INTERIOR SPECIALLY BRACED FRAME CORES
- MINIMIZED EFFECTS DUE TO TORSION
- PERMISSIBLE DRIFT VALUES

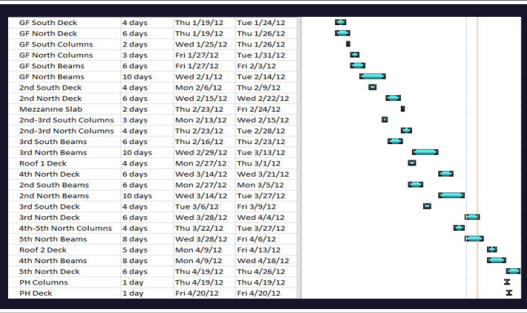


CONCLUSIONS

CONSTRUCTION MANAGEMENT BREADTH

- NORTH AND SOUTH CONSTRUCTION
- FASTER CONSTRUCTION TIME
- LOWER COST

GF South Deck	4 days	Thu 1/19/12	Tue 1/24/12
GF North Deck	6 days	Thu 1/19/12	Thu 1/26/12
GF South Columns	2 days	Wed 1/25/12	Thu 1/26/12
GF North Columns	3 days	Fri 1/27/12	Tue 1/31/12
GF South Beams	6 days	Fri 1/27/12	Fri 2/3/12
GF North Beams	10 days	Wed 2/1/12	Tue 2/14/12
2nd South Deck	4 days	Mon 2/6/12	Thu 2/9/12
2nd North Deck	6 days	Wed 2/15/12	Wed 2/22/12
Mezzanine Slab	2 days	Thu 2/23/12	Fri 2/24/12
2nd-3rd South Columns	3 days	Mon 2/13/12	Wed 2/15/12
2nd-3rd North Columns	4 days	Thu 2/23/12	Tue 2/28/12
3rd South Beams	6 days	Thu 2/16/12	Thu 2/23/12
3rd North Beams	10 days	Wed 2/29/12	Tue 3/13/12
Roof 1 Deck	4 days	Mon 2/27/12	Thu 3/1/12
4th North Deck	6 days	Wed 3/14/12	Wed 3/21/12
2nd South Beams	6 days	Mon 2/27/12	Mon 3/5/12
2nd North Beams	10 days	Wed 3/14/12	Tue 3/27/12
3rd South Deck	4 days	Tue 3/6/12	Fri 3/9/12
3rd North Deck	6 days	Wed 3/28/12	Wed 4/4/12
4th-5th North Columns	4 days	Thu 3/22/12	Tue 3/27/12
5th North Beams	8 days	Wed 3/28/12	Fri 4/6/12
Roof 2 Deck	5 days	Mon 4/9/12	Fri 4/13/12
4th North Beams	8 days	Mon 4/9/12	Wed 4/18/12
5th North Deck	6 days	Thu 4/19/12	Thu 4/26/12
PH Columns	1 day	Thu 4/19/12	Thu 4/19/12
PH Deck	1 day	Fri 4/20/12	Fri 4/20/12



CONCLUSIONS

SUSTAINABILITY BREADTH

- LEED SITE OPPORTUNITIES
- GREEN ROOF PERFORMANCE
- PHOTOVOLTAIC PANEL PERFORMANCE
- HEATING AND COOLING LOADS
- LEED RATING MAINTAINED

CONCLUSIONS

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- GREEN ROOF PERFORMANCE
- PHOTOVOLTAIC PANEL PERFORMANCE
- HEATING AND COOLING LOADS
- LEED RATING MAINTAINED

THANK YOU

QUESTIONS/COMMENTS

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Structural Option

CONNECTION CONSIDERATIONS

- REQUIRED TENSION STRENGTH : RyFyAg OR MAXIMUM LOAD EFFECT
- REQUIRED FLEXURAL STRENGTH : 1.1RyMp
- REQUIRED COMPRESSIVE STRENGTH : 1.1RyPn

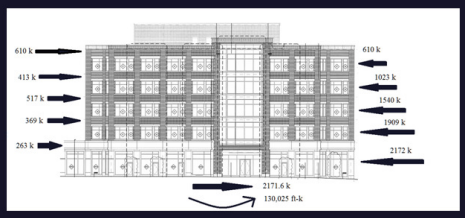
1776 WILSON BOULEVARD SKANSKA

Penn State University
Senior Thesis 2012

Faculty Advisor: Thomas Boothby

Joshua Urban
Structural Option

SEISMIC LOADS



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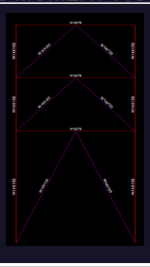
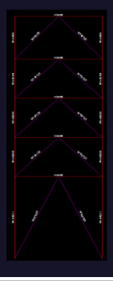
BRACED MOMENT FRAMES





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