AE SENIOR THESIS PRESENTATION

APRIL 15, 2008

OFFICE/RETAIL BUILDING

WASHINGTON, D.C.

Balfour Beatty Construction

DEREK BAUER
CONSTRUCTION MANAGEMENT

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OFFICE/RETAIL BUILDING – WASHINGTON, D.C.

PROJECT OVERVIEW

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Existing Building

New Construction

PROJECT OVERVIEW

PROJECT OVERVIEW

ANALYSIS 1
URBAN DEVELOPMENT

ANALYSIS 2
GREEN ROOF IMPLEMENTATION

ANALYSIS 3
BUILDING ENVELOPE PERFORMANCE

CONCLUSIONS

Q & A

-> Major renovation of existing office and retail building

LOCATION

- Downtown Washington, D.C. - Northwest

COST

- $33,867,000 (base building – core and shell)

SIZE

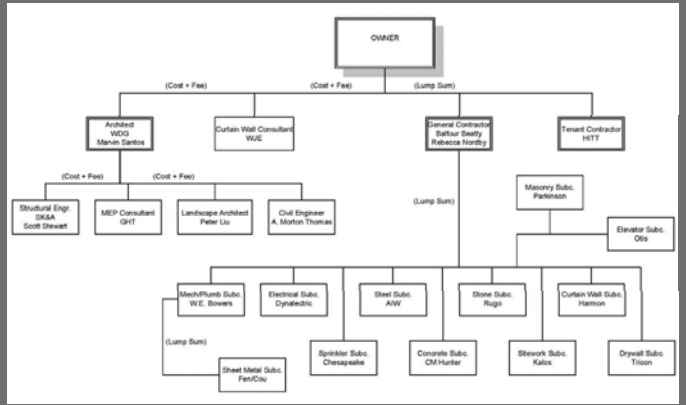
- 503,000 SF (gross) / 362,000 SF (occupied)
- 10-stories above grade, 3 underground parking levels, mechanical penthouse level

SCHEDULE

- August 2006 – September 2007 (13 months)

PROJECT DELIVERY METHOD

- Design-Bid-Build



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ARCHITECTURAL FEATURES

- Glass and metal panel curtain wall system
- Enhanced retail storefront
- Elegant new lobby area

- Monumental roof cornice
- Partial rooftop terrace

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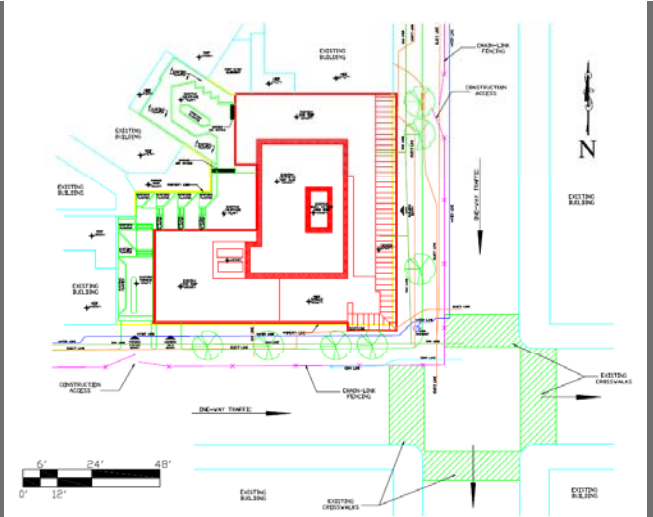

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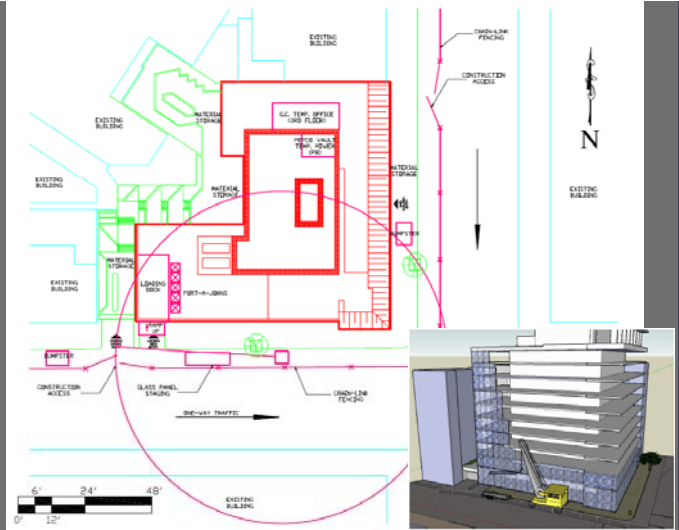
Q & A

SITE LOGISTICS

- Existing conditions
  - Site congestion



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CONCLUSIONS

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SITE LOGISTICS

- Existing conditions
  - Site congestion
- Curtain wall phase one

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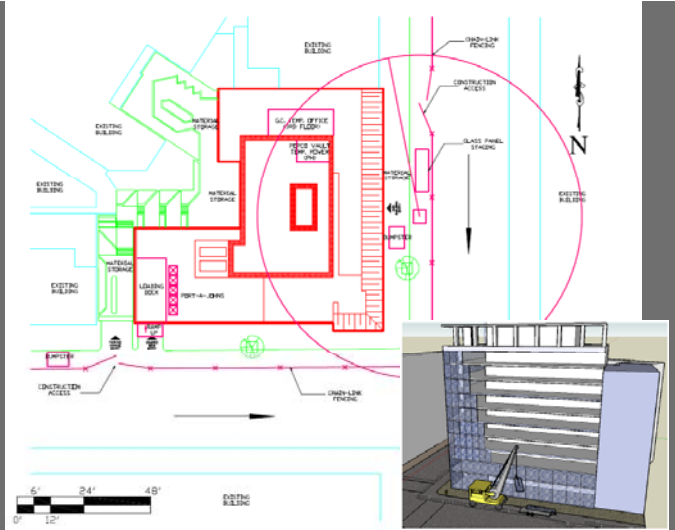
SITE LOGISTICS

- Existing conditions
  - Site congestion
- Curtain wall phase one
- Curtain wall phase two



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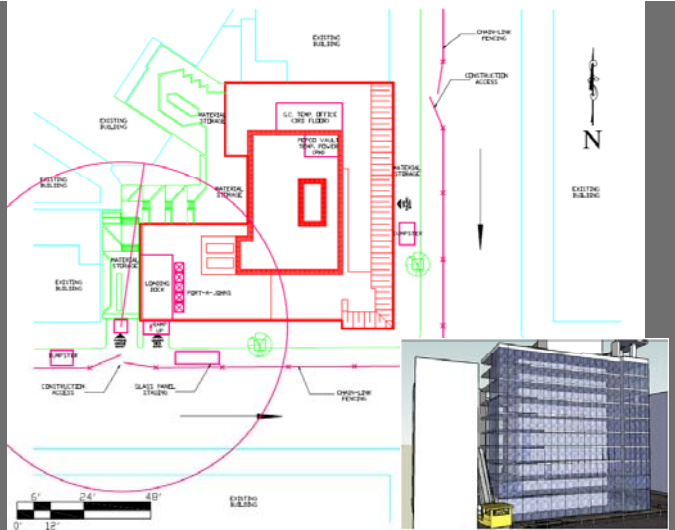
CONCLUSIONS

Q & A

SITE LOGISTICS

- Existing conditions
  - Site congestion
- Curtain wall phase one
- Curtain wall phase two
- Curtain wall phase three



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ANALYSIS 1

URBAN DEVELOPMENT

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URBAN DEVELOPMENT

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CONCLUSIONS

Q & A

PROBLEM

- Issues with renovation process
  - Selective interior demolition – critical path
  - Quality of existing building – flashing system leaks
  - Excessive number of submittals – slab penetrations

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URBAN DEVELOPMENT

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PROBLEM

- Issues with renovation process
  - Selective interior demolition – critical path
  - Quality of existing building – flashing system leaks
  - Excessive number of submittals – slab penetrations

GOAL

- Investigate building development methods
  - Renovation vs. demo/new construction
  - Compare cost, schedule, and constructability impact

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URBAN DEVELOPMENT

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CONCLUSIONS

Q & A

RESEARCH

- Create survey for understanding decision process developers face in early stages
  - Questions geared to identify factors involved, pros and cons of renovation vs. new construction
- Distribute out to industry members and gather feedback
- Analyze the office/retail building renovation project based on industry input

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URBAN DEVELOPMENT

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CONCLUSIONS

Q & A

DECISION FACTORS

- Project budget and schedule
- First cost versus life cycle cost
  - Owner's investment into building
  - Leasing arrangement – i.e. payment of utility bills
- Constructability
- Existing building conditions
  - Hazardous materials, salvage value
- Zoning, code compliance
  - Height, set back distance, F.A.R.
- Local market and demand
  - How much tenants are willing to pay

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Office/Retail Building Cost of Demolition and New Construction	
Mass Demolition	$1,949,467
Office/Retail Building	$38,285,921
Underground Parking Garage	$7,387,855
Penthouse Structure	$250,000
Subtotal	$47,873,243
Location Factor	99.1
Contractor Fees (10% GC's, 5% Overhead, 4% Profit)	19%
TOTAL COST	**$56,456,437**

URBAN DEVELOPMENT

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CONCLUSIONS

Q & A

COST IMPACT

- Renovation: $33,867,000
- Demo/New Construction: $56,456,437
  - Higher first cost
  - Better quality structure
    - Increased efficiency and sustainability
  - Freedom in design
    - Potential to increase leasable floor area

URBAN DEVELOPMENT

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CONCLUSIONS

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SCHEDULE IMPACT

- Renovation: 13 months
- Demo/New Construction: 2 years +
  - New activities: Demolition and site clearing, excavation, foundation and substructure, superstructure
  - Elimination of delays from unknown conditions – fewer change orders

CONSTRUCTABILITY IMPACT

- Demolition phase – challenging
- New construction – fairly basic concrete structure

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URBAN DEVELOPMENT

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Q & A

CONCLUSION

- Owner is long-term holder – life cycle cost important
- Stable market for office space – low risk of leasing
- Existing building maximized zoning height allowance
- Existing building structurally stable – salvage value
- Owner had push to get tenants in ASAP, strong value engineering efforts

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- Existing building maximized zoning height allowance
- Existing building structurally stable – salvage value
- Owner had push to get tenants in ASAP, strong value engineering efforts

– Speculated that owner would not have invested more money upfront to construct new building

- Potential for owner to increase performance and value based on development method of renovation

ANALYSIS 2

GREEN ROOF IMPLEMENTATION

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GREEN ROOF IMPLEMENTATION

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CONCLUSIONS

Q & A

PROBLEM

- Not much consideration given for increasing sustainability of building design and construction

GOAL

- Implement a green roof retrofit into office/retail building
- Keep first costs low compared to life cycle cost savings

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GREEN ROOF IMPLEMENTATION

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BENEFITS

- Environmental
  - Reducing Urban Heat Island Effect
  - Improving air quality – plants filtering and re-oxygenating air
- Economic
  - Longer lifespan of roof
  - Energy savings
  - Increase property value and marketability
- Other
  - Reducing storm water runoff

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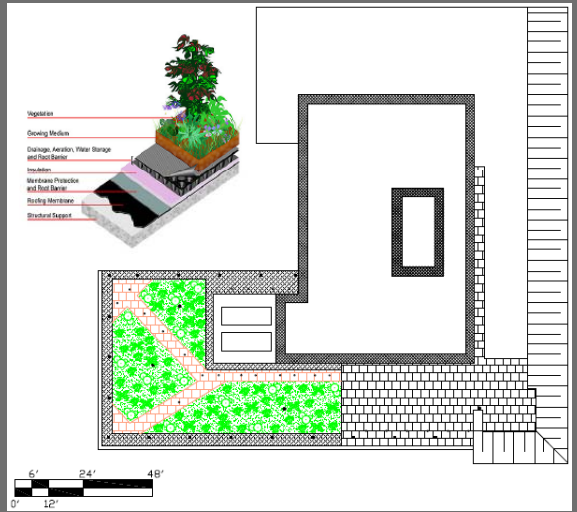

GREEN ROOF IMPLEMENTATION

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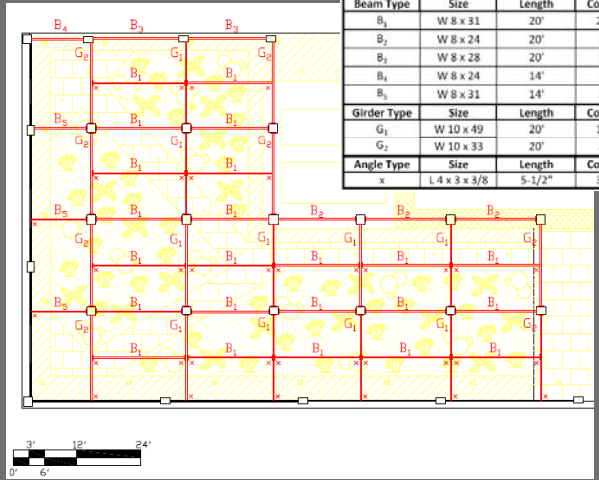
Q & A

PROPOSED DESIGN

- Hydrotech Intensive Garden Roof System
  - 8” soil depth
- Southwest corner of existing roof
  - Ties into new roof deck for easy public access
  - Maximum exposure to sunlight for plant growth
  - Vegetation-free zones at all roof penetrations
    - Davit bases
    - Plumbing wet stack



Structural Retrofit Schedule			
Beam Type	**Size**	**Length**	**Count**
B_1	W 8 x 31	20'	23
B_2	W 8 x 24	20'	3
B_3	W 8 x 28	20'	2
B_4	W 8 x 24	14'	1
B_5	W 8 x 31	14'	3
Girder Type	**Size**	**Length**	**Count**
G_1	W 10 x 49	20'	10
G_2	W 10 x 33	20'	8
Angle Type	**Size**	**Length**	**Count**
x	L 4 x 3 x 3/8	5-1/2"	36

GREEN ROOF IMPLEMENTATION

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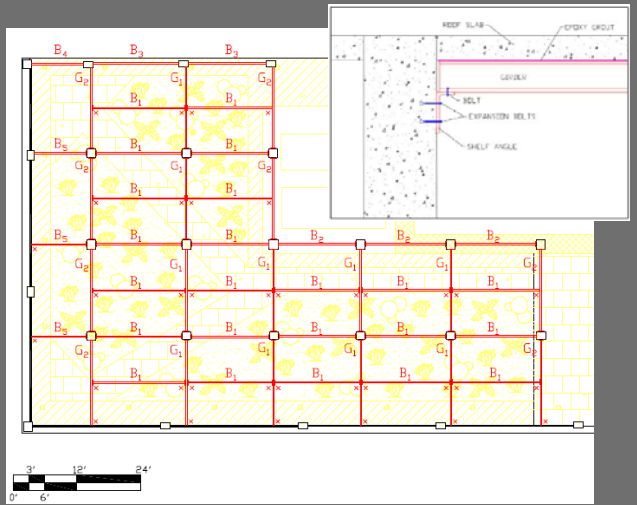
CONCLUSIONS

Q & A

STRUCTURAL BREADTH – STEEL RETROFIT

- Existing roof slab design loads
  - 30 psf live load + roof self weight
- Proposed green roof loads
  - 100 psf live load (occupancy) + 45 psf (green roof dead load, saturated soil)
- pcaSlab results – existing slab fails
- AISC Manual used to design structural steel beams and girders – retrofit beneath roof slab



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STRUCTURAL BREADTH – STEEL RETROFIT

- Epoxy grout to tie into existing roof slab
- Members tied into existing columns
  - Shelf angles used for more flexibility in expansion bolt location
  - Important that existing rebar is not struck
- pcaColumn used to verify existing columns can withstand added load of green roof

GREEN ROOF IMPLEMENTATION

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CONCLUSIONS

Q & A

COST IMPACT

- Green roof retrofit: $244,624
  - Plus regular maintenance for vegetation and soil
  - 20% increase in structural system cost

SCHEDULE IMPACT

- Steel – during installation of other structural steel
  - Productivity: 550 LF/day + connection time
  - Impact: push structural steel installation ahead one week to not affect MEP equipment schedule
- Green roof – after installation of roof membrane
  - Impact: increase roofing installation time by one week

COST IMPACT - Green Roof Implementation

RS Means #	Item	Description	Quantity	Unit	Cost / Unit	Cost
-	Hydrotech Intesive Garden Roof	Green Roof	7,016	SF	$25.00	$175,400
05 12 23.75	Structural Steel Members	W 8 x 24	74	LF	$36.11	$2,672
	Structural Steel Members	W 8 x 28	40	LF	$41.11	$1,644
	Structural Steel Members	W 8 x 31	502	LF	$44.61	$22,394
	Structural Steel Members	W 10 x 33	160	LF	$47.11	$7,538
	Structural Steel Members	W 10 x 49	200	LF	$66.61	$13,322
05 12 23.40	Lightweight Framing	L 4 x 3 x 3/8	140	LB	$3.32	$466
-	Lightweight Framing	L 8 x 6 x 1 Shelf Angle	2,829	LB	$3.32	$9,392
05 05 23.10	Bolts and Hex Nuts	Expansion Anchors	36	EA	$20.69	$745
03 61 20.10	Construction Grout	Epoxy Grout	976	SF	$13.60	$13,274
				Subtotal:		$246,846
				Location Factor:		99.1
				TOTAL COST OF GREEN ROOF:		**$244,624**

GREEN ROOF IMPLEMENTATION

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CONCLUSIONS

Q & A

CONSTRUCTABILITY IMPACT

- Inhibited by renovation – more expensive
- Coordination issue with MEP systems in 10th floor plenum space
  - Extra coordination meetings required between structural steel and MEP contractors
- Scanning for existing rebar in each column
  - Shelf angles instead of double angles from steel members for more flexibility in bolt location

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GREEN ROOF IMPLEMENTATION

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CONCLUSIONS

Q & A

CONCLUSION

- Many added benefits for implementing green roof retrofit
- Life cycle cost savings: increase life in roof, higher property value
- Energy savings TBD in Analysis 3
- High first cost: $244,624

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GREEN ROOF IMPLEMENTATION

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CONCLUSIONS

Q & A

CONCLUSION

- Many added benefits for implementing green roof retrofit
- Life cycle cost savings: increase life in roof, higher property value
- Energy savings TBD in Analysis 3
- High first cost: $244,624

– Speculated that owner would not have been interested in proposed green roof retrofit
  - First cost too high
  - No other consideration given for sustainable design or construction

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ANALYSIS 3

BUILDING ENVELOPE PERFORMANCE

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BUILDING ENVELOPE PERFORMANCE

CONCLUSIONS

Q & A

PROBLEM

- No insulation in existing exterior walls
- Renovation did not address improving thermal performance of building envelope
  - Poor thermal comfort, high energy costs

GOAL

- Improve thermal performance building envelope
- Keep first costs low compared to life cycle cost savings

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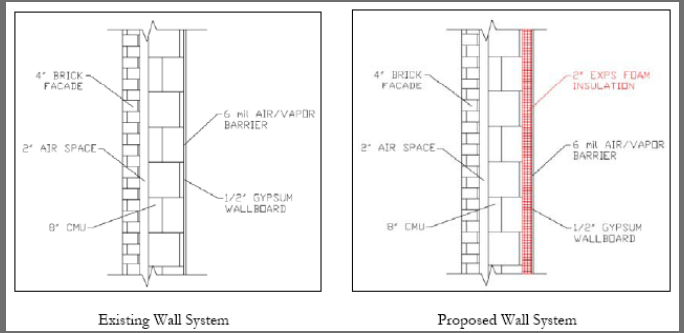

Existing Wall System

Proposed Wall System

BUILDING ENVELOPE PERFORMANCE

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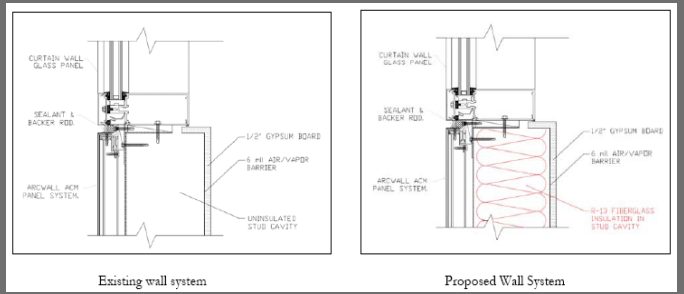
PROPOSED IMPROVEMENTS

- Add insulation to block wall (north & west)
  - 2" layer of EXPS foam insulation



Existing wall system

Proposed Wall System

BUILDING ENVELOPE PERFORMANCE

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PROPOSED IMPROVEMENTS

- Add insulation to block wall (north & west)
  - 2" layer of EXPS foam insulation
- Add insulation behind curtain wall metal panels
  - R-13 fiberglass insulation in stud cavity

BUILDING ENVELOPE PERFORMANCE

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MECHANICAL BREADTH – THERMAL ANALYSIS

- U-value calculation for walls
  - North and West façades: 0.073 from 0.275

North & West Façade - Wall

(Area = 30,655 SF)

Existing System			Proposed System		
Material	Thickness	R-Value	Material	Thickness	R-Value
Exterior Air Film	-	0.33	Exterior Air Film	-	0.33
Brick Façade	4"	0.44	Brick Façade	4"	0.44
Air Space	2"	1.02	Air Space	2"	1.02
CMU	8"	0.71	CMU	8"	0.71
Air/Vapor Barrier	6 mil	-	EXPS Rigid Foam Board	2"	10.0
Gypsum Wallboard	1/2"	0.45	Air/Vapor Barrier	6 mil	-
Interior Air Film	-	0.68	Gypsum Wallboard	1/2"	0.45
			Interior Air Film	-	0.68
SUM of R-Values		3.63	SUM of R-Values		13.63
U-Value of System = 0.275			U-Value of System = 0.073		

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BUILDING ENVELOPE PERFORMANCE

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MECHANICAL BREADTH – THERMAL ANALYSIS

- U-value calculation for walls
  - North and West façades: 0.073 from 0.275
  - Curtain wall metal panels: 0.068 from 0.360

Curtain Wall - Metal Panels

(Area = 9,100 SF)

Existing System			Proposed System		
Material	Thickness	R-Value	Material	Thickness	R-Value
Exterior Air Film	-	0.33	Exterior Air Film	-	0.33
Aluminum Panel	1/32"	0.63	Aluminum Panel	1/32"	0.63
Thermo-Plastic Core	1/8"		Thermo-Plastic Core	1/8"	
Aluminum Panel	1/32"		Aluminum Panel	1/32"	
Stud Cavity (Air)	3-1/2"	1.02	Insulated Stud Cavity (R-13)	3-1/2"	13.0
Air/Vapor Barrier	6 mil	-	Air/Vapor Barrier	6 mil	-
Gypsum Wallboard	1/2"	0.45	Gypsum Wallboard	1/2"	0.45
Interior Air Film	-	0.68	Interior Air Film	-	0.68
SUM of R-Values		2.78	SUM of R-Values		14.76
U-Value of System = 0.360			U-Value of System = 0.068		

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BUILDING ENVELOPE PERFORMANCE

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MECHANICAL BREADTH – THERMAL ANALYSIS

- U-value calculation for walls
  - North and West façades: 0.073 from 0.275
  - Curtain wall metal panels: 0.068 from 0.360
- U-value calculation for green roof
  - Best case scenario – dry soil

Roof - Green Roof Portion
BEST CASE SCENARIO - Dry Soil
(Area = 7,016 SF)

Existing System			Proposed System		
Material	Thickness	R-Value	Material	Thickness	R-Value
Exterior Air Film	-	0.33	Exterior Air Film	-	0.33
Stone Ballast	1/2"	0.05	Vegetation	2" - 12"	-
Membrane	2"	1.70	Growing Medium	8"	16.0
EXPS Rigid Foam Board	2"	10.0	Filter Fabric	1/8"	-
Concrete Slab	8"	0.58	Drainage Layer	2"	1.07
Interior Air Film	-	0.74	Moisture Retention Mat	3/16"	-
			EXPS Rigid Foam Board	2"	10.0
			Root Barrier	1/32"	-
			Membrane	2"	1.70
			Concrete Slab	8"	0.58
			Interior Air Film	-	0.74
SUM of R-Values		13.40	SUM of R-Values		30.42
U-Value of System = 0.075			U-Value of System = 0.033		

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MECHANICAL BREADTH – THERMAL ANALYSIS

- U-value calculation for walls
  - North and West façades: 0.073 from 0.275
  - Curtain wall metal panels: 0.068 from 0.360
- U-value calculation for green roof
  - Best case scenario – dry soil
  - Worst case scenario – saturated soil

Roof - Green Roof Portion
WORST CASE SCENARIO - Saturated Soil
(Area = 7,016 SF)

Existing System			Proposed System		
Material	Thickness	R-Value	Material	Thickness	R-Value
Exterior Air Film	-	0.33	Exterior Air Film	-	0.33
Stone Ballast	1/2"	0.05	Vegetation	2" - 12"	-
Membrane	2"	1.70	Growing Medium	8"	-
EXPS Rigid Foam Board	2"	10.0	Filter Fabric	1/8"	-
Concrete Slab	8"	0.58	Drainage Layer	2"	-
Interior Air Film	-	0.74	Moisture Retention Mat	3/16"	-
			EXPS Rigid Foam Board	2"	10.0
			Root Barrier		-
			Membrane		1.70
			Concrete Slab	8"	0.58
			Interior Air Film	-	0.74
SUM of R-Values		13.40	SUM of R-Values		13.35
U-Value of System = 0.075			**U-Value of System = 0.075**		

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Average U-Value Calculation - Proposed Green Roof System
Avg. U = ((112/365)*0.075)+((1-(112/365))*0.033)
Avg. U = 0.046 (Btu/ft²•°F•h)

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- U-value calculation for walls
  - North and West façades: 0.073 from 0.275
  - Curtain wall metal panels: 0.068 from 0.360
- U-value calculation for green roof
  - Best case scenario – dry soil
  - Worst case scenario – saturated soil
  - Average U-value: 0.046 from 0.075

BUILDING ENVELOPE PERFORMANCE

MECHANICAL BREADTH – THERMAL ANALYSIS

- Degree hours – heating and cooling

Monthly Climatic Data - Washington, D.C.							
Month	Int Air Temp	Ext Air Temp	Difference	Deg Days	Deg Hours	Heating	Cooling
JAN	70	35	35	1085	26,040	26,040	
FEB	70	38	32	904	21,696	21,696	
MAR	70	46	24	744	17,856	17,856	
APR	70	56	14	420	10,080	10,080	
MAY	70	66	4	124	2,976	2,976	
JUN	70	75	-5	150	-3,600		3,600
JUL	70	79	-9	270	-6,480		6,480
AUG	70	77	-7	210	-5,040		5,040
SEP	70	71	-1	30	-720		720
OCT	70	59	11	341	8,184	8,184	
NOV	70	49	21	630	15,120	15,120	
DEC	70	39	31	961	23,064	23,064	
					SUM (hrs °F)	125,016	15,840

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North & West Façade - Wall	Existing	Proposed	Difference
U Value (Btu / ft²·°F·h)	0.275	0.073	
Area (ft²)	30,655	30,655	
Annual Heat Loss (Btu)	1,053,900,507	279,762,680	
Annual Heat Loss (kWh)	**308,868**	**81,990**	**226,877**
Annual Heat Gain (Btu)	133,533,180	35,446,990	
Annual Heat Gain (kWh)	**39,135**	**10,388**	**28,746**
		Annual Heat Loss and Gain (kWh)	255,624
		Energy Savings (kWh)	319,530
		Energy Cost ($/kWh)	0.123
		Total Annual Energy Cost Savings	$39,302

MECHANICAL BREADTH – THERMAL ANALYSIS

- Degree hours – heating and cooling
- Annual heat loss or gain (Q) = A x U x ΔT
- HVAC system efficiency = 0.8
- Energy cost savings
  - North & West façades: $39,302

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Curtain Wall - Metal Panels	Existing	Proposed	Difference
U Value (Btu / ft²·°F·h)	0.360	0.068	
Area (ft²)	9,100	9,100	
Annual Heat Loss (Btu)	409,552,416	77,359,901	
Annual Heat Loss (kWh)	**120,028**	**22,672**	**97,356**
Annual Heat Gain (Btu)	51,891,840	9,801,792	
Annual Heat Gain (kWh)	**15,208**	**2,873**	**12,335**
		Annual Heat Loss and Gain (kWh)	109,691
		Energy Savings (kWh)	137,114
		Energy Cost ($/kWh)	0.123
		Total Annual Energy Cost Savings	$16,865

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MECHANICAL BREADTH – THERMAL ANALYSIS

- Degree hours – heating and cooling
- Annual heat loss or gain (Q) = A x U x ΔT
- HVAC system efficiency = 0.8
- Energy cost savings
  - North & West façades: $39,302
  - Curtain wall metal panels: $16,865

Green Roof	Existing	Proposed	Difference
U Value (Btu / ft²·°F·h)	0.075	0.046	
Area (ft²)	7,016	7,016	
Annual Heat Loss (Btu)	65,783,419	40,241,910	
Annual Heat Loss (kWh)	**19,279**	**11,794**	**7,485**
Annual Heat Gain (Btu)	8,335,008	5,098,802	
Annual Heat Gain (kWh)	**2,443**	**1,494**	**948**
		Annual Heat Loss and Gain (kWh)	8,434
		Energy Savings (kWh)	10,542
		Energy Cost ($/kWh)	0.123
		Total Annual Energy Cost Savings	$1,297

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MECHANICAL BREADTH – THERMAL ANALYSIS

- Degree hours – heating and cooling
- Annual heat loss or gain (Q) = A x U x ΔT
- HVAC system efficiency = 0.8
- Energy cost savings
  - North & West façades: $39,302
  - Curtain wall metal panels: $16,865
  - Green roof: $1,297

COST IMPACT - Building Envelope Improvements						
RS Means #	Item	Description	Quantity	Unit	Cost / Unit	Cost
07 21 13.10	Rigid Insulation	Extruded polystyrene, 2" thick, R10	30,655	SF	$1.46	$44,756
07 21 16.20	Blanket Insulation for Walls	Foil faced fiberglass, 3.5" thick, R13	9,100	SF	$0.82	$7,462
				Subtotal:		$52,218
				Location Factor:		99.1
			TOTAL COST OF BUILDING ENVELOPE IMPROVEMENTS:			**$51,748**

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COST IMPACT

- Proposed wall systems: $51,748

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COST IMPACT

- Proposed wall systems: $51,748
- Proposed green roof: $244,624

COST IMPACT - Green Roof Implementation

RS Means #	Item	Description	Quantity	Unit	Cost / Unit	Cost
-	Hydrotech Intesive Garden Roof	Green Roof	7,016	SF	$25.00	$175,400
05 12 23.75	Structural Steel Members	W 8 x 24	74	LF	$36.11	$2,672
	Structural Steel Members	W 8 x 28	40	LF	$41.11	$1,644
	Structural Steel Members	W 8 x 31	502	LF	$44.61	$22,394
	Structural Steel Members	W 10 x 33	160	LF	$47.11	$7,538
	Structural Steel Members	W 10 x 49	200	LF	$66.61	$13,322
05 12 23.40	Lightweight Framing	L 4 x 3 x 3/8	140	LB	$3.32	$466
-	Lightweight Framing	L 8 x 6 x 1 Shelf Angle	2,829	LB	$3.32	$9,392
05 05 23.10	Bolts and Hex Nuts	Expansion Anchors	36	EA	$20.69	$745
03 61 20.10	Construction Grout	Epoxy Grout	976	SF	$13.60	$13,274
				Subtotal:		$246,846
				Location Factor:		99.1
				TOTAL COST OF GREEN ROOF:		**$244,624**

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SCHEDULE IMPACT

- Proposed wall systems
  - EXPS foam insulation: 730 SF/day
    - 7 days with 3 carpenters
    - Installed before air/vapor barrier and drywall
  - R-13 fiberglass insulation: 1,150 SF/day
    - 4 days with 2 carpenters
    - Installed before curtain wall metal panels

  -> No significant impact to overall project schedule
- Proposed green roof
  - No significant impact (Analysis 2)

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DEREK BAUER
CONSTRUCTION MANAGEMENT

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CONSTRUCTABILITY IMPACT

- Proposed wall systems
  - Important that insulation joints are properly sealed
- Proposed green roof
  - Stored materials on southwest part of roof
    - Metal panels, canopy steel, MEP equipment could be stored elsewhere
  - Coordination issues with other trades
    - MEP systems in plenum space (Analysis 2)

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CONCLUSION

- Thermal performance of building envelope can be greatly improved with proposed retrofits
- Proposed wall systems
  - $51,748 first cost versus $56,167/yr energy savings
- Proposed green roof
  - $244,624 first cost versus $1,297/yr energy savings

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CONCLUSION

- Thermal performance of building envelope can be greatly improved with proposed retrofits
- Proposed wall systems
  - $51,748 first cost versus $56,167/yr energy savings
- Proposed green roof
  - $244,624 first cost versus $1,297/yr energy savings

– Speculated that owner would have only been interested in proposed wall system improvements
  - First cost pays for itself in less than one year
  - Green roof not nearly worth the energy savings of thermal performance improvements

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CONCLUSIONS

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URBAN DEVELOPMENT

- Many factors involved with developer's decision on development method
  - Goal – make money as efficiently as possible
- Analyzed office/retail building renovation compared to demo and new construction
  - New construction
    - Nearly twice the cost and schedule impact
    - Owner interested in moving tenants in ASAP – renovation is best decision

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GREEN ROOF IMPLEMENTATION

- Many environmental and economical benefits
- Coordination issues likely with MEP trades
- Upfront cost of nearly $250,000 likely not worth implementing for building owner

BUILDING ENVELOPE PERFORMANCE

- Wall systems thermal performance improvements pay for themselves in less than one year
- Green roof thermal performance improvements are minimal compared to upfront cost

OFFICE/RETAIL BUILDING – WASHINGTON, D.C.

QUESTIONS?

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