Penn State AE Senior Capstone Project

Dominic Coassolo | Construction Management

Dr. Robert Leicht – CM Advisor

Office Building – G
Eastern USA

Office Building – G
Eastern USA

Presentation Outline:

A. Project Background
B. Analysis 1: Implementation of Photovoltaic Glass
   1. PV Description and Replacement
   2. Structural Implications
   3. Payback Period
   4. Electrical Breadth – System Tie-In
C. Analysis 2: Material Delivery During Peak Traffic Hours
   1. Pedestrian Traffic Information
   2. Material Delivery Analysis
   3. Proposed Delivery Schedule
D. Analysis 3: Use of a Tieback System
   1. Tieback and Raker Analysis
   2. Cost Implications
   3. Schedule Impact
E. Lessons Learned
F. Acknowledgements

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Office Building-G Information:

- 14 Stories – 4 Levels Underground Parking
- Gross SF – 649,100 SF
- Building – 380,100 SF , Garage – 269,000 SF

Project Information:

- Design-Bid-Build
- GMP with Owner - $70,000,000
- Construction Dates: November 2009 – September 2012
- LEED Certification: Silver

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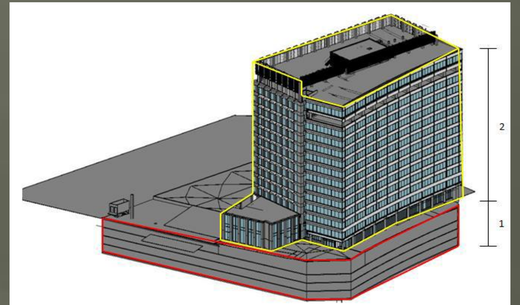
Project Background



1. Four Level Underground Parking Garage (Outlined in RED)
2. 14 Story Office Building (Outlined in Yellow)

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Cast In Place Concrete:

- **Predominant system**
- **7’ Slabs with 5000 psi load on core floors (4-13)**
- **24”x 24” Columns : 10,000 psi (Garage) and 6000 psi (Building)**

MEP:

- **3 Variable Speed Drive Chillers**
- **VAV System on Each Floor**
- **Fully Integrated Building Automation System**
- **Penthouse – Main Mechanical Room**

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Façade:
- Precast Concrete
- Blast Façade
- Curtain Wall on Southern Elevation
  - Glass and Aluminum
  - Segmented

Special Considerations:
- Metro Station (West Side of Building)
- Metro Parking

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Project Background

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Problem Identification:

- **Project to attain LEED Silver**
- **Opportunity to Implement PV Panels**

Research Goal:

- **Replace Current Curtain Wall Glass With Transparent PV Panels**
- **Analyze Structural and System Payback Period**

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Photovoltaic Information:

- **Centennial Solar**
- **Fully Transparent Panels**
- **Thin Film Module**
- **Double Glazing**
- **Size: 3’-8” x 8’-5”**
- **Power: 100W per Panel**

PV Description

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PV Replacement

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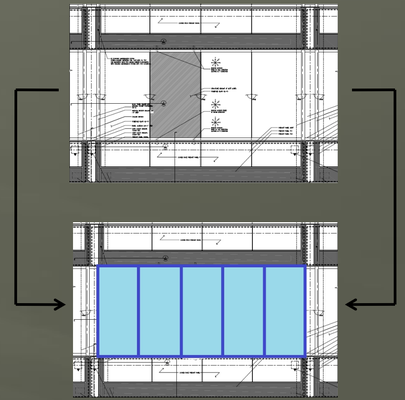
Replacement Strategy:

- Four Glass Panels (Currently)
- Five PV Panels to be Implemented
- Southern Façade Only
- 52 PV Panels per Floor
- 676 Total PV Panels on Southern Façade
- LEED Credits: Additional 1-3 Points



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Structural Analysis of PV System:

- **Current Weight of Glass on Curtain Wall: 300,000 lbs**
- **Weight per Panel: 321 lbs**
- **Weight x Four Panels: 1285 lbs**
- **PV Panel Weight: 247 lbs**
- **Weight x Five Panels: 1235 lbs**
- **1235 lbs < 1285 lbs → OK!**

Structural Impact

Structural Implications Analysis			
Glass Panels		**Photovoltaic Panels**	
Total Panels	936	**Total Panels**	676
Total Weight	300,000 lbs	**Total Weight**	167,000 lbs
Weight Per Panel	321 lbs	**Weight Per Panel**	247 lbs
Total load on Space (Panel Wt. x 4)	1285 lbs	**Total load on Space (Panel Wt. x 5)**	1235 lbs

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Energy Production:

- **System Size: 67.6 kW**
- **Average Cost of PV System: $7.50/Watt in 2011 (U.S. Dept. of Energy)**
- **AC Energy per Year: 53,469 kWh**
- **Energy Value: $4,170.58**
- **146.5 kWh – Daily System Energy Production**

Station Identification	
City:	NA
State:	NA
Latitude:	NA
Longitude:	NA
Elevation:	47 m
PV System Specifications	
DC Rating:	67.6 kW
DC to AC Derate Factor	0.77
AC Rating	52.1 kW
Array Type	Fixed Tilt
Array Tilt	90.0°
Array Azimuth	180.0°
Energy Specifications	
Cost of Electricity	7.8 ¢ kWh

Payback Period

PV Energy Watts Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.46	5689	443.74
2	3.92	5798	452.24
3	3.46	5268	410.9
4	2.91	3961	308.96
5	2.56	3266	254.75
6	2.46	2821	220.04
7	2.55	3070	239.46
8	2.81	3558	277.52
9	3.25	4354	339.61
10	4.04	6103	476.03
11	3.35	5108	398.42
12	2.8	4473	348.89
Year	3.13	53469	4170.58

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Payback Period Analysis:

- **Total Estimated Cost: $507,000**
- **Rebates and Incentives:**
  - **-15% Installation Cost ($25,000 max.)**
  - **-$500/kWh Produced each year**
- **Retail Cost of Energy: 0.1268$/kWh**
- **Estimated 1.00% increase each year**
- **System Cost with Incentives: $482,000**
- **25 Year Savings: $1,036,420**
- **25 Year Value: $554,420**

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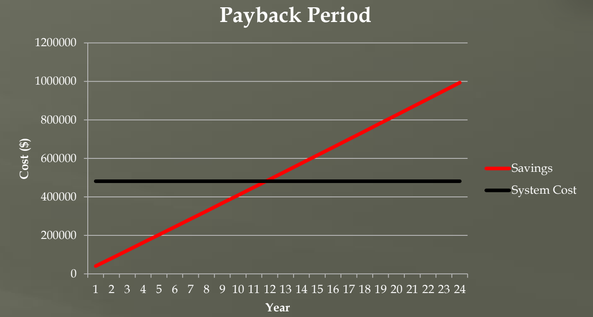
Payback Period



Year 12: System Cost will be Recouperated

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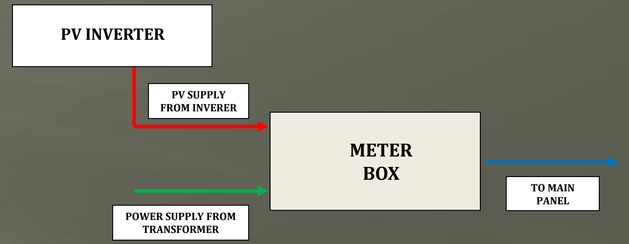
PV Connection:
- Supply – Side Interconnection

Electrical Components
- DC Wire
- DC Disconnects
- Inverter
- AC Disconnects
- AC Wire
- Service – Tap Meter Box

Electrical Tie-In



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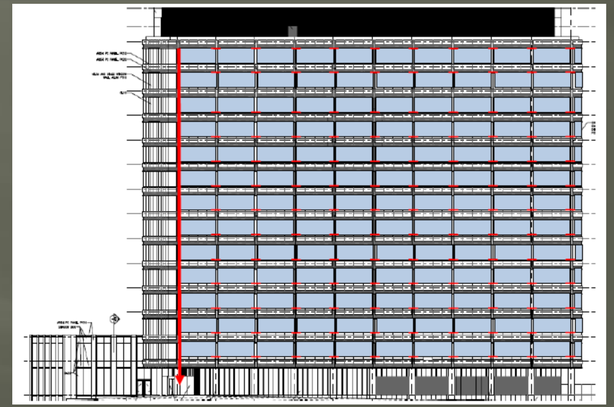
Inverter Selection:
- System Size: 67.6 kW
- Inverter Size: 75 kW

Wire Run:
- DC Wire Connects each Panel
- Run Down Southwest Edge of Curtain Wall
- Inverter Location: First Floor Electrical Room
- Transformer Located on First Floor
- AC Wire Run to Main Electrical Room (Top Floor Underground Parking)

Electrical Tie-In



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Problem Identification:

- **Project Being Between Metro Station and Parking**
- **Pedestrian Traffic**

•Research Goal:

- **Analyze Pedestrian Traffic**
- **Develop Material Delivery Schedule In Accordance With Pedestrian Traffic**

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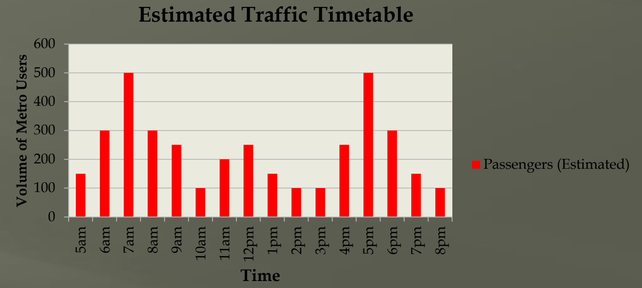
Metro Station Statistics:

- **1.36 Million Users per Year**
- **Approx. 3,700 Users per Day**
- **Peak Hours:**
  - **6am – 9am**
  - **11am – 1pm**
  - **4pm – 6pm**

Pedestrian Traffic Data



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Material Delivery Analysis:

- **Week of Sept. 12, 2011- Sept. 16, 2011**
- **Trade Work on Floors 2 – 14 (exclude 9&10)**
- **Floor 7: Framing**
  - **-300 LF total**
  - **- RS Means: 2 man crew, 54 LF/day**
  - **- 50 studs total/day**
  - **- 250 studs total (estimated)**
  - **- 1 truckload/5 pallets**
  - **- Unloading Time: 50 minutes**

Material Delivery Analysis

Floor 7: Wall Framing - Summary				
Total Framing (LF)	**RS Means**	**Material Per Day**	**Total Studs Per Floor**	**Studs Per Pallet**
300 LF	2 workers - 54 LF per day	50 studs	250	50

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Material Delivery Analysis:

- Analyzed by Truckload and Number of Pallets
- Unloading Includes Hoists and Cranes if Needed
- Materials will be placed in location for Use
- Total Unloading Time: 27 hours and 10 minutes

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Material Delivery Analysis

Material Delivery Details (Week of 9/12/11 - 9/16/11)					
Floor	**Trade**	**# of Truckloads of Material**	**Pallets Per Truck**	**Unloading Time Per Pallet**	**Total Time to Place Material in Area**
2	Drywall	2	10	10 min	3 hours 20 minutes
3	MEP Wall Close-In	1	5	10 min	50 minutes
4	Elect. Rough-In	1	5	10 min	50 minutes
5	Plumbing Rough-In	1	5	10 min	50 minutes
6	Mech. Rough -In	2	5	12 min	2 hours
7	Wall Framing	1	5	10 min	50 minutes
8	Door Frames	1	5	15 min	1 hour 50 minutes
9	None	NA	NA	NA	NA
10	None	NA	NA	NA	NA
11	Sprinkler Distribution	1	5	10 min	50 minutes
12	Elect. Distribution	1	5	10 min	50 minutes
13	Duct Distribution	5	8	15 min	10 hours
14	MEP Risers	1	5	10 min	50 minutes
	TRASH	2	NA	5 min	10 minutes
				Total Time to Unload Materials	**27 hours 10 minutes**

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Proposed Delivery Schedule:

- **Week prior to Sept. 12, 2011- Sept. 16, 2011**
- **Three to Four Trucks per Day**
- **Enter and Exit Through North Entrance**
- **South Entrance for Special Deliveries and Emergencies Only**

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Material Delivery Schedule

Material Delivery Schedule (Week of 9/5/11 - 9/9/11)			
Day	**Trade Materials Delivered**	**Time Arrival**	**Time Departure**
Monday (9/5)	MEP Wall Close-In	Truck 1 - 9:00:00 AM	Truck 1 - 9:50:00 AM
Monday (9/5)	Elect. Rough-In	Truck 1 - 10:00:00 AM	Truck 1 - 10:50:00 AM
Monday (9/5)	Plumbing Rough-In	Truck 1 - 2:00:00 PM	Truck 1 - 2:50:00 PM
Tuesday (9/6)	Wall Framing	Truck 1 - 9:00:00 AM	Truck 1 - 9:50:00 AM
Tuesday (9/6)	Sprinkler Distribution	Truck 1 - 10:00:00 AM	Truck 1 - 10:50:00 AM
Tuesday (9/6)	Elect. Distribution	Truck 1 - 2:00:00 PM	Truck 1 - 2:50:00 PM
Tuesday (9/6)	MEP Risers	Truck 1 - 3:00:00 PM	Truck 1 - 3:50:00 PM
Tuesday (9/6)	Trash	Truck 1 - 4:00:00 PM	Truck 2 - 4:05:00 PM
Wednesday (9/7)	Duct Distribution	Truck 1 - 9:00:00 AM	Truck 1 - 11:00:00 AM
Wednesday (9/7)	Duct Distribution	Truck 2 - 11:00:00 AM	Truck 2 - 1:00:00 PM
Wednesday (9/7)	Duct Distribution	Truck 3 - 1:00:00 PM	Truck 3 - 3:00:00 PM
Wednesday (9/7)	Duct Distribution	Truck 4 - 3:00:00 PM	Truck 4 - 5:00:00 PM
Thursday (9/8)	Duct Distribution	Truck 5 - 9:00:00 AM	Truck 5 - 11:00:00 AM
Thursday (9/8)	Door Frames	Truck 1 - 1:00:00 PM	Truck 1 - 2:50:00 PM
Thursday (9/8)	Mech. Rough -In	Truck 1 - 3:00:00 PM	Truck 1 - 4:00:00 PM
Friday (9/9)	Mech. Rough -In	Truck 2 - 9:00:00 AM	Truck 2 - 10:00:00 AM
Friday (9/9)	Drywall	Truck 1 - 10:00:00 AM	Truck 1 - 11:40:00 AM
Friday (9/9)	Drywall	Truck 2 - 2:00:00 PM	Truck 2 - 3:40:00 PM
Friday (9/9)	Trash	Truck 2 - 4:00:00 PM	Truck 2 - 4:05:00 PM

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Problem Identification:

- **Metro Adjacent To Project Site**
- **Excavation Support Is Critical**

Research Goal:

- **Replace Raker System With Tieback System**
- **Analyze Cost and Schedule Impact**

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Analysis Three

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Tieback System

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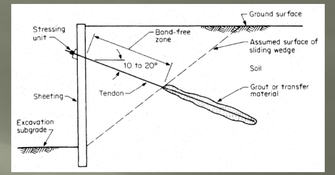
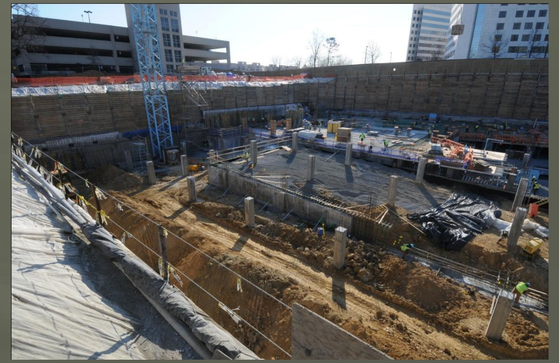
Tieback System:

- Three Tier System
- Soldier Piles and Lagging
- 925 LF
- Post tensioning in Foundation Wall
- Provides room to work





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Raker System

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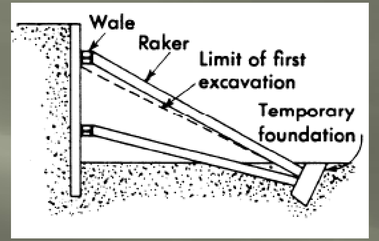
Raker System:

- **Only on Metro Side**
- **165 LF**
- **Braced Framing**
- **Braced Against Foundation Slab**



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Analysis Three

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Cost Analysis

Presentation Outline:

A. Project Background
B. Analysis 1: Implementation of Photovoltaic Glass
   1. PV Description and Replacement
   2. Structural Implications
   3. Payback Period
   4. Electrical Breadth – System Tie-In
C. Analysis 2: Material Delivery During Peak Traffic Hours
   1. Pedestrian Traffic Information
   2. Material Delivery Analysis
   3. Proposed Delivery Schedule
D. Analysis 3: Use of a Tieback System
   1. Tieback and Raker Analysis
   2. Cost Implications
   3. Schedule Impact
E. Lessons Learned
F. Acknowledgements

Cost Evaluation:

- **Tieback Cost: $550,000**
- **Raker Cost: $276,000**
- **Tieback Only Cost: $648,550**
- **Total Savings: $177,450**

Excavation System Cost Analysis			
Current System			
	Total LF	**Total Cost ($)**	**Cost/LF**
Tieback System	925	$550,000	$595
Raker System	165	$276,000	$1,673
Total	**1090**	**$826,000**	
Proposed System			
Tieback System	1090	$648,550	$595
Total	**1090**	**$648,550**	
Total System Cost Savings = $177,450			

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Schedule Acceleration:

- **Excavation: Aug. 20, 2010 – Dec. 10, 2010**
- **Tieback: 95 days**
  - **-760 hours**
  - **- 50 min/LF**
- **Raker: 30 days**
  - **-240 hours**
  - **- 1 hr. 30 min/LF**

Tieback Only:

- **Save 11 Working Days**
- **No effect on Critical Path**

Schedule Acceleration

Schedule Acceleration Analysis			
Current System			
	Total LF	**Time (hours)**	**Time/LF**
Tieback System	925	760	50 min
Raker System	165	240	1 hr 30 min
Total	**1090**	**1000**	
Proposed System			
Tieback System	1090	909	50 min
Total	**1090**	**909**	
Total Schedule Savings = ~ 11 Working Days or 90 Hours			

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Lessons Learned

Presentation Outline:

Analysis 1 (Implementation of PV):

- Feasibility Study Must Be Developed Early in Project
- State Incentives Help Greatly In System Cost

Analysis 2 (Material Delivery Schedule):

- Delivery Schedule Critical To Keep Project On Track

Analysis 3 (Tieback System):

- One System Is More Cost and Schedule Efficient

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QUESTIONS?