

SCIENCE AND TECHNOLOGY CENTER  
COPPIN STATE UNIVERSITY  
BALTIMORE, MD



PENN STATE ARCHITECTURAL ENGINEERING SENIOR CAPSTONE PROJECT

NICHOLAS ZITTERBART | CONSTRUCTION OPTION  
ADVISOR: DR. JOHN MESSNER



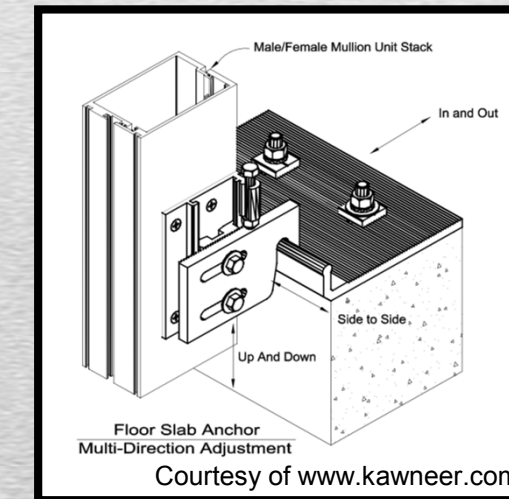
PROJECT OVERVIEW



ANALYSIS 1 | SCHEDULE RESEQUENCE



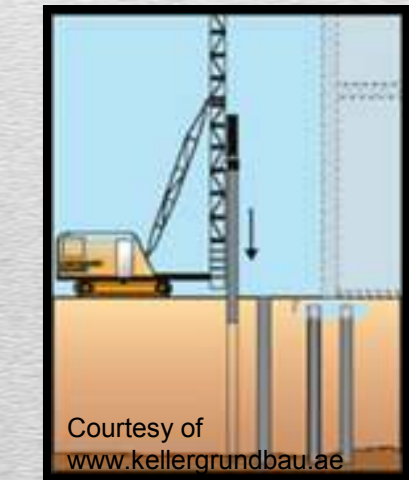
ANALYSIS 2 | MODULARIZATION OF CURTAIN WALL



ANALYSIS 3 | FINNED TUBE RADIATOR DESIGN



ANALYSIS 4 | ALTERNATIVE FOUNDATION SYSTEM

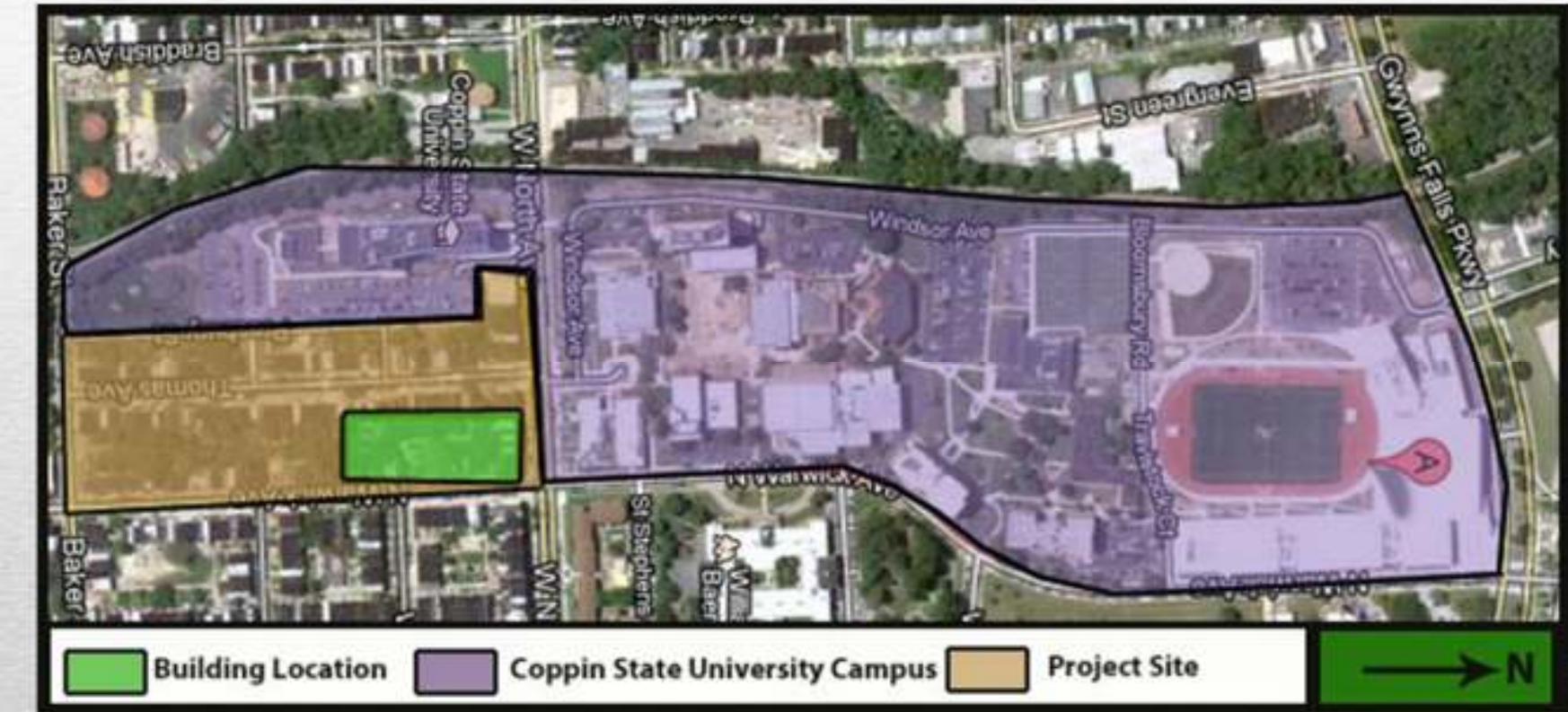




**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW**
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

<b>BUILDING NAME</b>	<b>COPPIN STATE SCIENCE AND TECHNOLOGY CENTER</b>
<b>LOCATION</b>	BALTIMORE, MARYLAND
<b>BUILDING OCCUPANT</b>	COPPIN STATE UNIVERSITY
<b>OCCUPANCY TYPE</b>	BUSINESS (B)
<b>SIZE</b>	135,000 GSF
<b>NUMBER OF STORIES ABOVE GRADE</b>	4 PLUS PENTHOUSE
<b>BUILDING TIMELINE</b>	OCTOBER 2012 – OCTOBER 2014
<b>OVERALL PROJECT COST</b>	\$76.2M
<b>PROJECT DELIVERY METHOD</b>	CM AT RISK
<b>CONTRACT TYPE</b>	GMP



Site Layout



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW**
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
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**OWNER** | UNIVERSITY OF MARYLAND  
**CONSTRUCTION MANAGER** | BARTON MALOW COMPANY  
**ARCHITECT** | CANNON DESIGN  
**MECHANICAL & ELECTRICAL ENGINEER** | CANNON DESIGN  
**CIVIL ENGINEERS** | SITE RESOURCES, INC.  
**STRUCTURAL ENGINEER** | COLUMBIA ENGINEERING, INC. |  
**GEOTECHNICAL ENGINEER** | T.L.B. ASSOCIATES, INC. |  
**PLUMBING / FIRE PROTECTION** | WFT ENGINEERING, INC.





**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW**
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
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- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

## Building Systems

### Structural System

Cast-in-Place Concrete – Floors 1 to 4  
Structural Steel - Penthouse

### Exterior Façade System

- Brick Veneer
- Terracotta Wall Tiles
- Curtain Wall
- Metal Panels

### Mechanical System

6 Air Handling Units - VAV System  
3 Boilers (Expansion for 7) – Partially Serves Perimeter Heating System

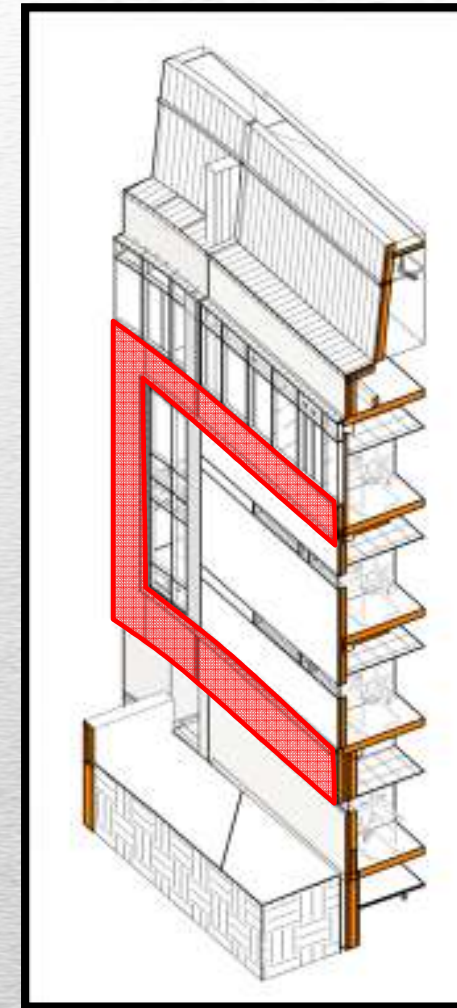


Rendering at SW Corner



## OUTLINE

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. **ANALYSIS 1: SCHEDULE RESEQUENCE**
  - I. **BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES
  - IV. RESULTS
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION



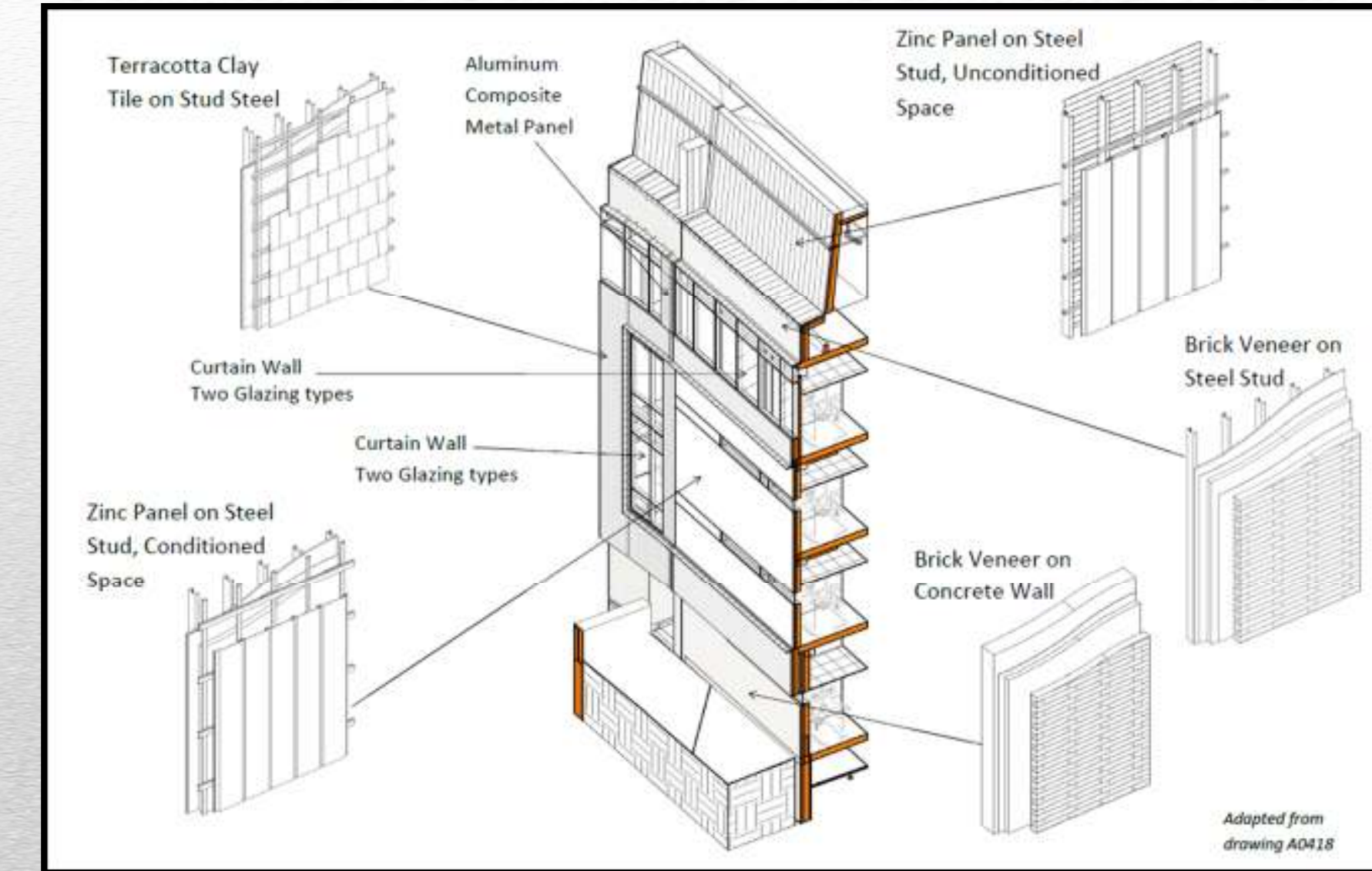
Area of Terracotta Tiles

## Problem Background

Five different cladding assemblies with multiple materials increase installation time

## Potential Solutions

1. Replace terracotta wall tiles on east elevation with current brick veneer
2. Implement Lean Management Principles (SIPS & Last Planner System)



Wall Assemblies at East Elevation



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. **ANALYSIS 1: SCHEDULE RESEQUENCE**
- I. BACKGROUND & SOLUTIONS
- II. **SCHEDULE/COST EVALUATION**
- III. LEAN PRINCIPLES
- IV. RESULTS
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

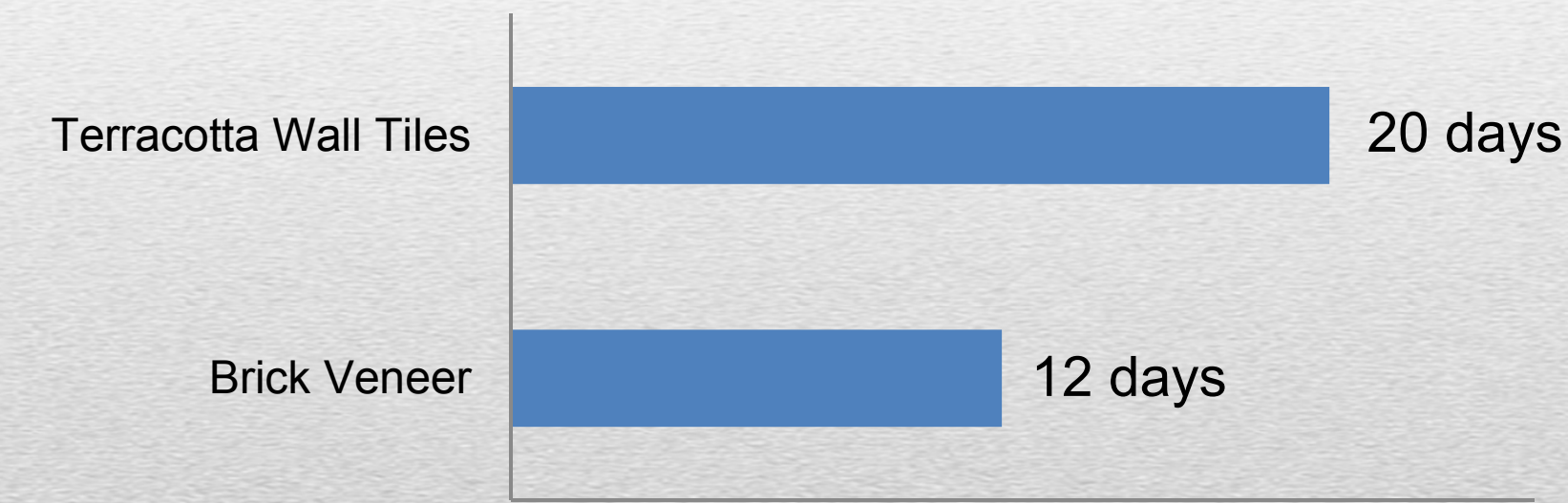
## Original Schedule

East Elevation – Perimeter Studs & Sheathing  
**40 days**

East Elevation – Exterior Brick Veneer  
**38 days**

## Schedule Evaluation

Cladding Assembly Comparison



## Cost Evaluation

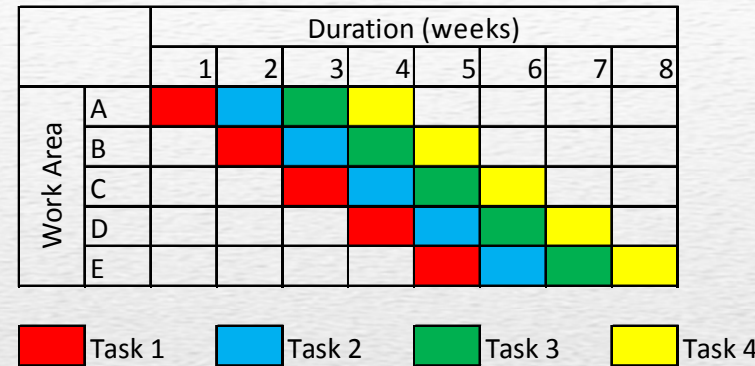
Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
<b>Baseline Cost</b>				
Terracotta Wall Tile	7567.8	S.F.	\$ 14.97	\$ 113,290
Brick Veneer	7567.8	S.F.	\$ 26.54	\$ 200,849
<b>Variance</b>				<b>(add) \$ 87,559</b>



## OUTLINE

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. **ANALYSIS 1: SCHEDULE RESEQUENCE**
- IV. BACKGROUND & SOLUTIONS
- V. SCHEDULE/COST EVALUATION
- VI. **LEAN PRINCIPLES**
- VII. RESULTS
- VIII. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- IX. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- X. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- XI. CONCLUSION

## SIPS Example



## LPS Example



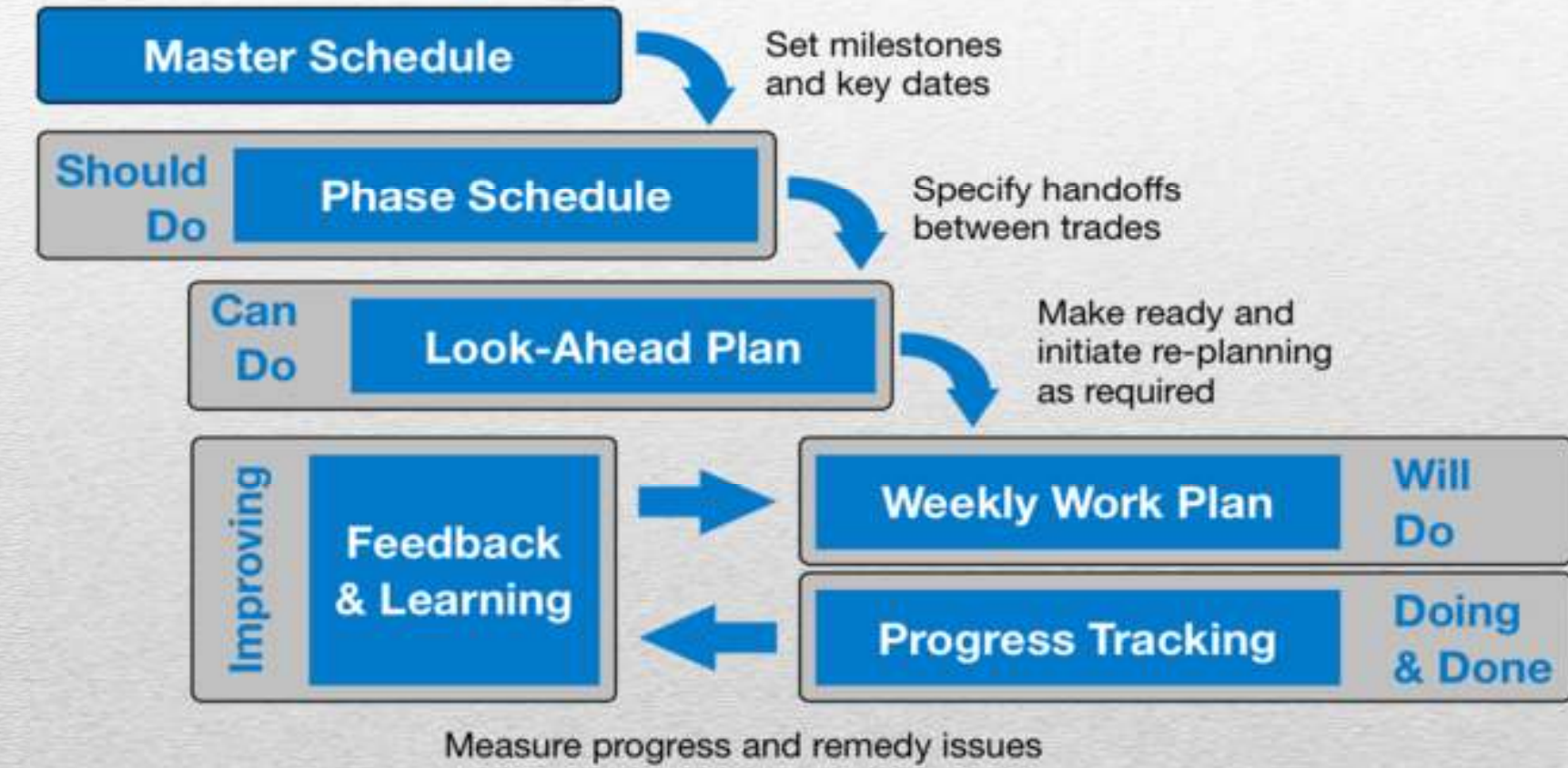
## Short Interval Production Schedule (SIPS)

- Utilized with repeatable construction activities
- Activities blocked as single unit on matrix
- Lean Principles: Flow & Value

## Last Planner System (LPS)

- Trade commitments for scheduled durations
- Lean Principles: Pull, Flow & Value

## Last Planner System





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- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. **ANALYSIS 1: SCHEDULE RESEQUENCE**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES
- IV. **RESULTS**
- V. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- VI. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VII. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VIII. CONCLUSION

## Results

### Exterior Cladding Assembly Replacement

- Additional \$87,559 to budget
- Reduced schedule by 8 days

Constructability of east façade would be simplified and schedule reduced, however it is a cost prohibitive option.

### Lean Management Principles

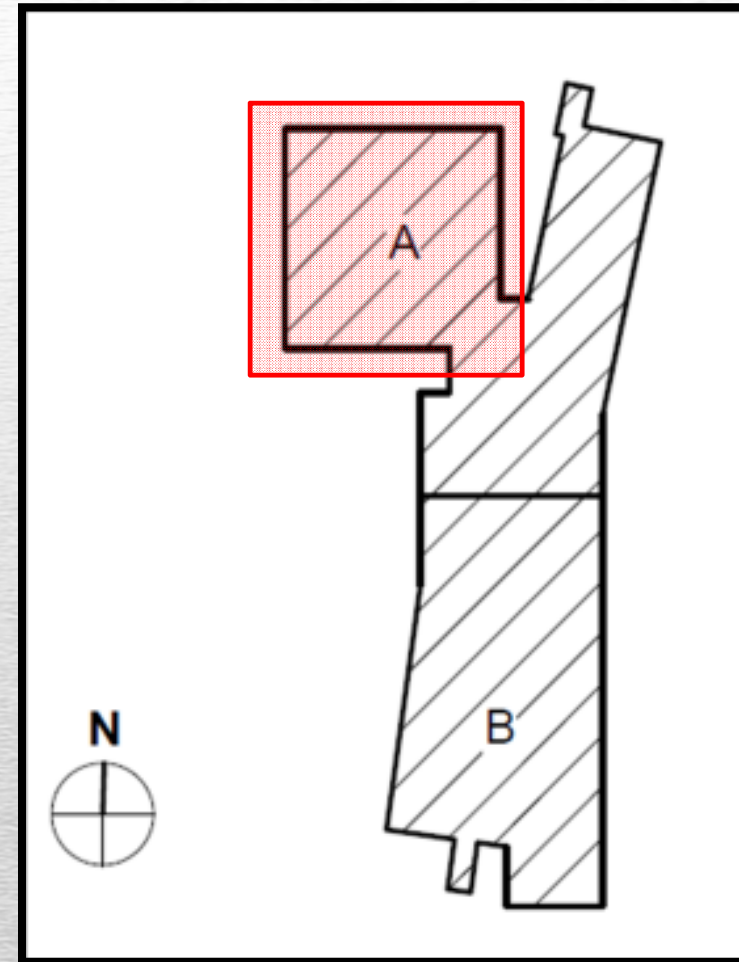
- Reduce accident frequency by up to 66%
- Potential for major schedule acceleration and cost savings

Instituting lean building practices will improve communication and provide more effective scheduling methods.



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- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
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  - I. BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES
  - IV. RESULTS
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION



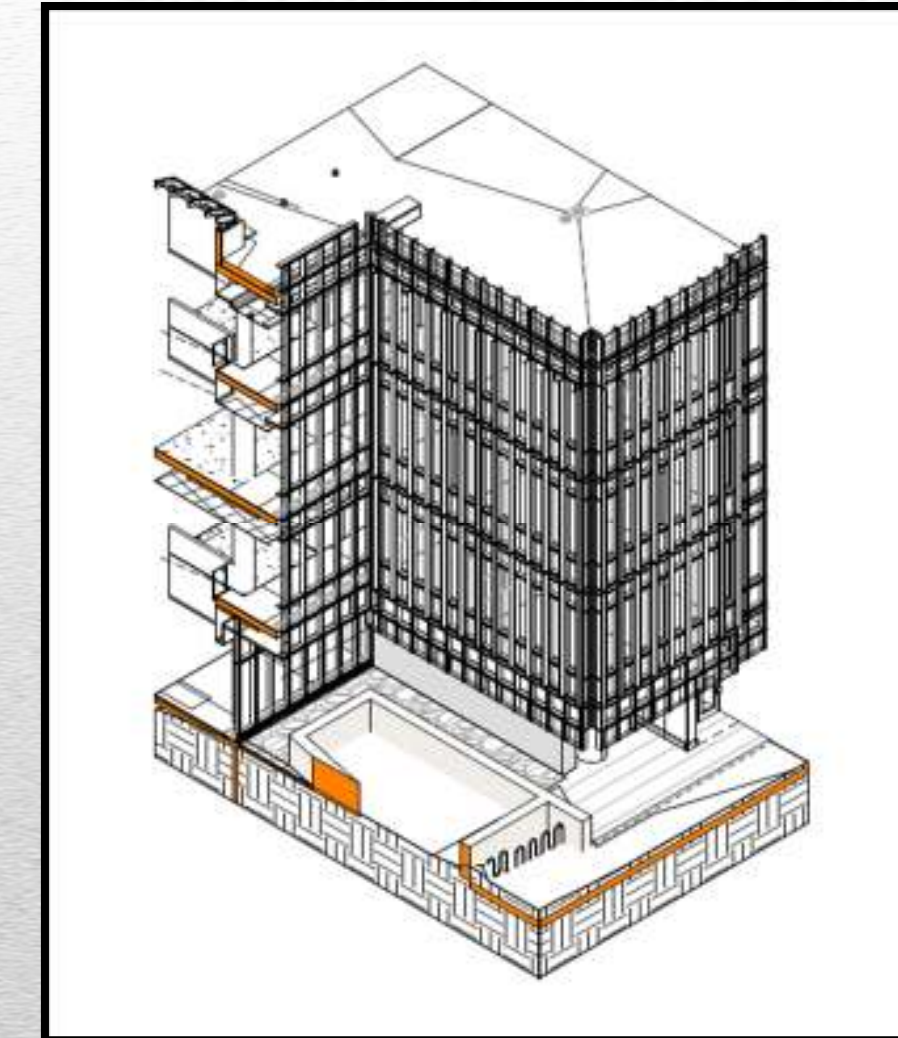
Location of Major Curtain Wall Area

## Problem Background

Stick-built curtain wall system leads to longer on-site installation and increased labor costs

## Potential Solutions

Implement a unitized curtain wall panel system that can be delivered on a just-in-time basis

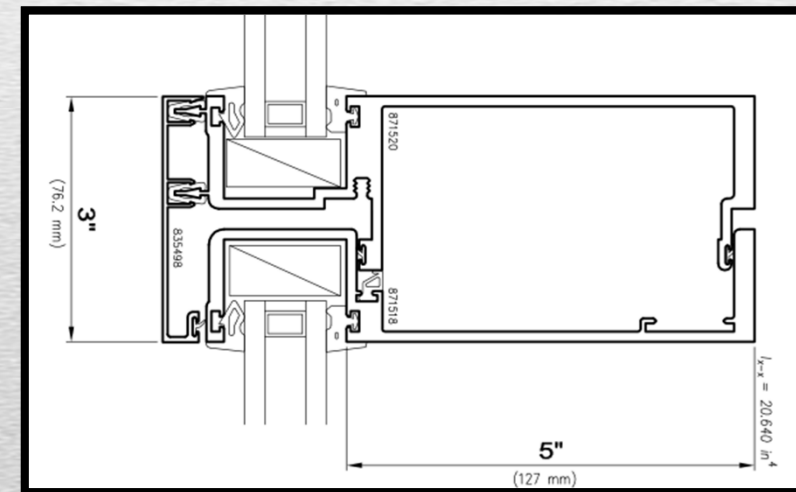


Building Section Isometric at Northwest Tower



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL**
  - I. BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES
  - IV. RESULTS
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION



**Plan of Connection Detail**

**Curtain Wall Panel Manufacturer:  
Wausau Window and Wall Systems**

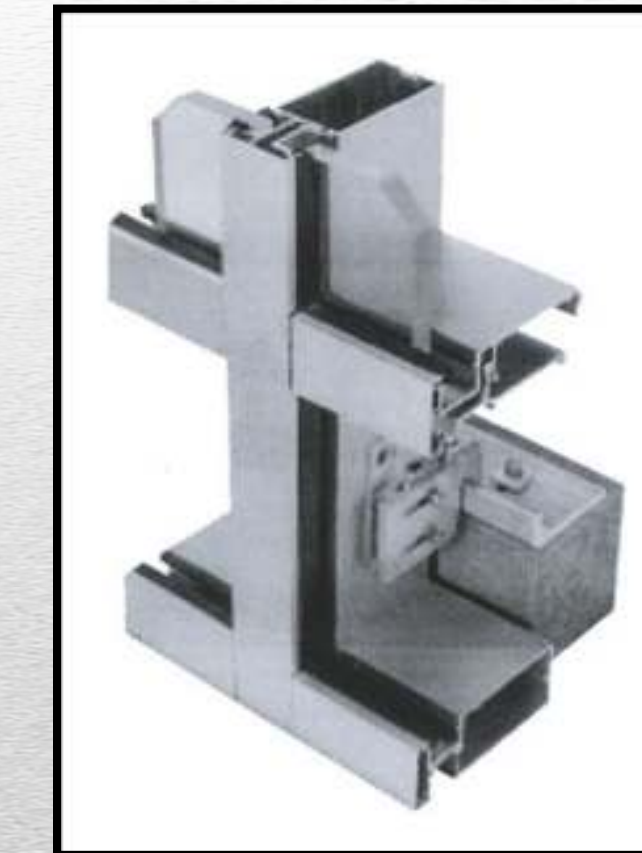
Utilizes interlocking frame design to accommodate seismic, live and thermal building movements (3/4" vertical movement)

Offered in 4 sided structural glazed panels per specifications

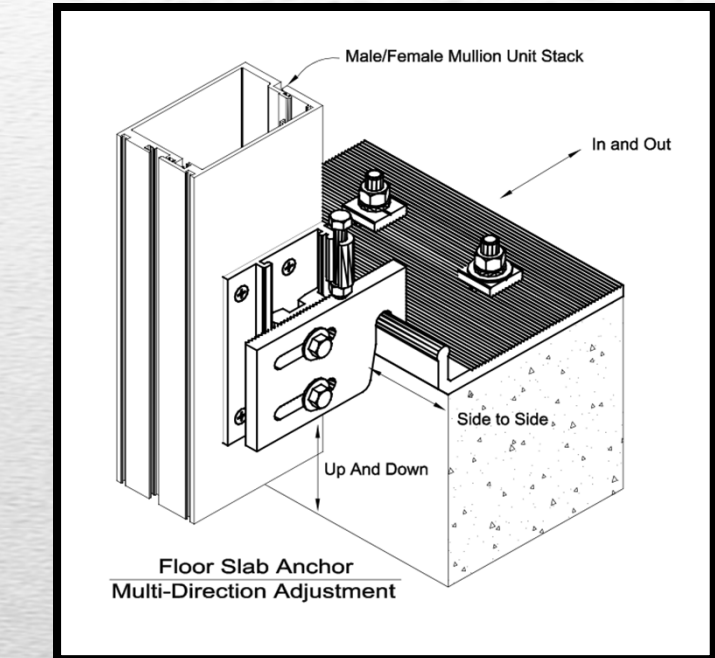
Unique 'jack-bolt' anchoring option for fast installation

Case Study: Metro Park 6 Building – Alexandria, VA

- Installed 52 panel sections in 6.5 hours (7.5 min/panel)



**Anchor Isometric Detail**



**Panel Anchor Detail**



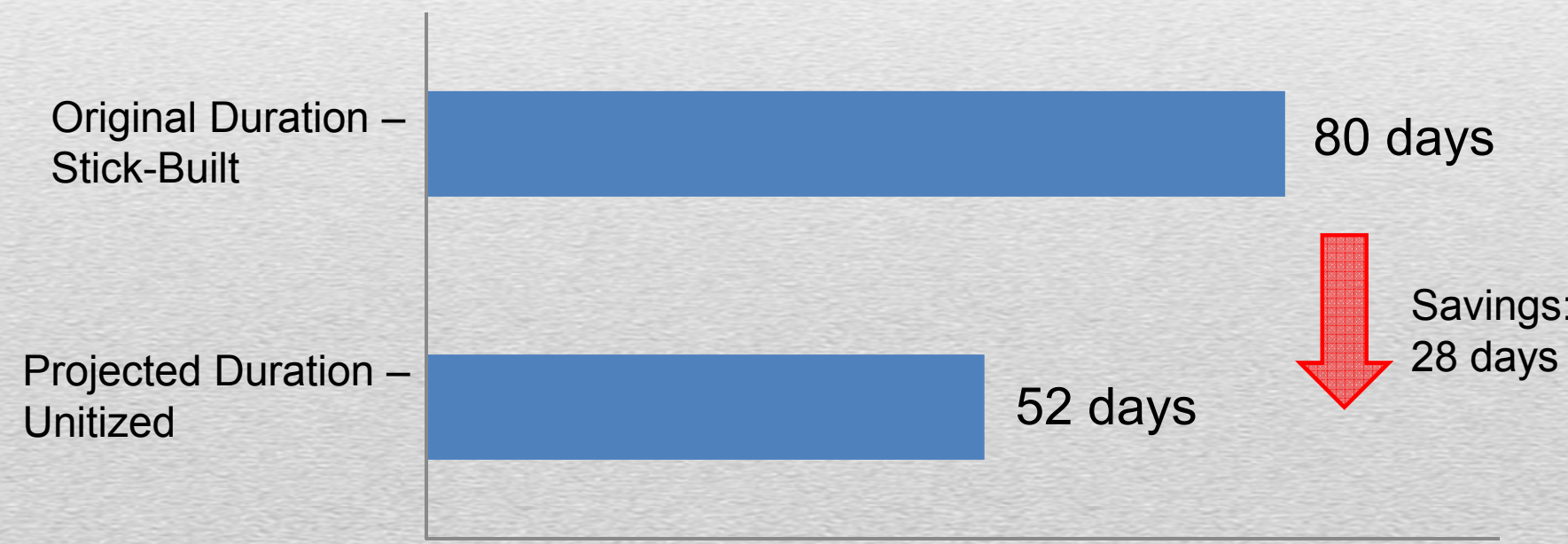
**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION**
  - III. LEAN PRINCIPLES
  - IV. RESULTS
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

## Schedule Evaluation

\*Northwest Tower based upon 52 panels/day  
 \*Remaining building area based upon 26 panels/day

Northwest Tower – 303 Panels @ 52 panels/day = 6 days  
 Balance of Panels – 480 Panels @ 26 panels/day = 19 days  
 Trimout/Caulk Panels – 783 Panels @ 30 panels/day = 27 days  
**Total = 52 days**



## Cost Evaluation

\*Using 1 erection crew and 1 staging crew for unitized panels

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Stick Built System	34,675	SF	\$ 180.00	\$ 6,241,500.00
<b>Subtotal</b>				<b>\$ 6,241,500.00</b>
Unitized System	34,675	SF	\$ 153.00	\$ 5,305,275.00
Staging Crew for Panels	34,675	SF	\$ 9.35	\$ 324,211.00
<b>Subtotal</b>				<b>\$ 5,629,486.00</b>
<b>Total Savings</b>				<b>\$612,014</b>



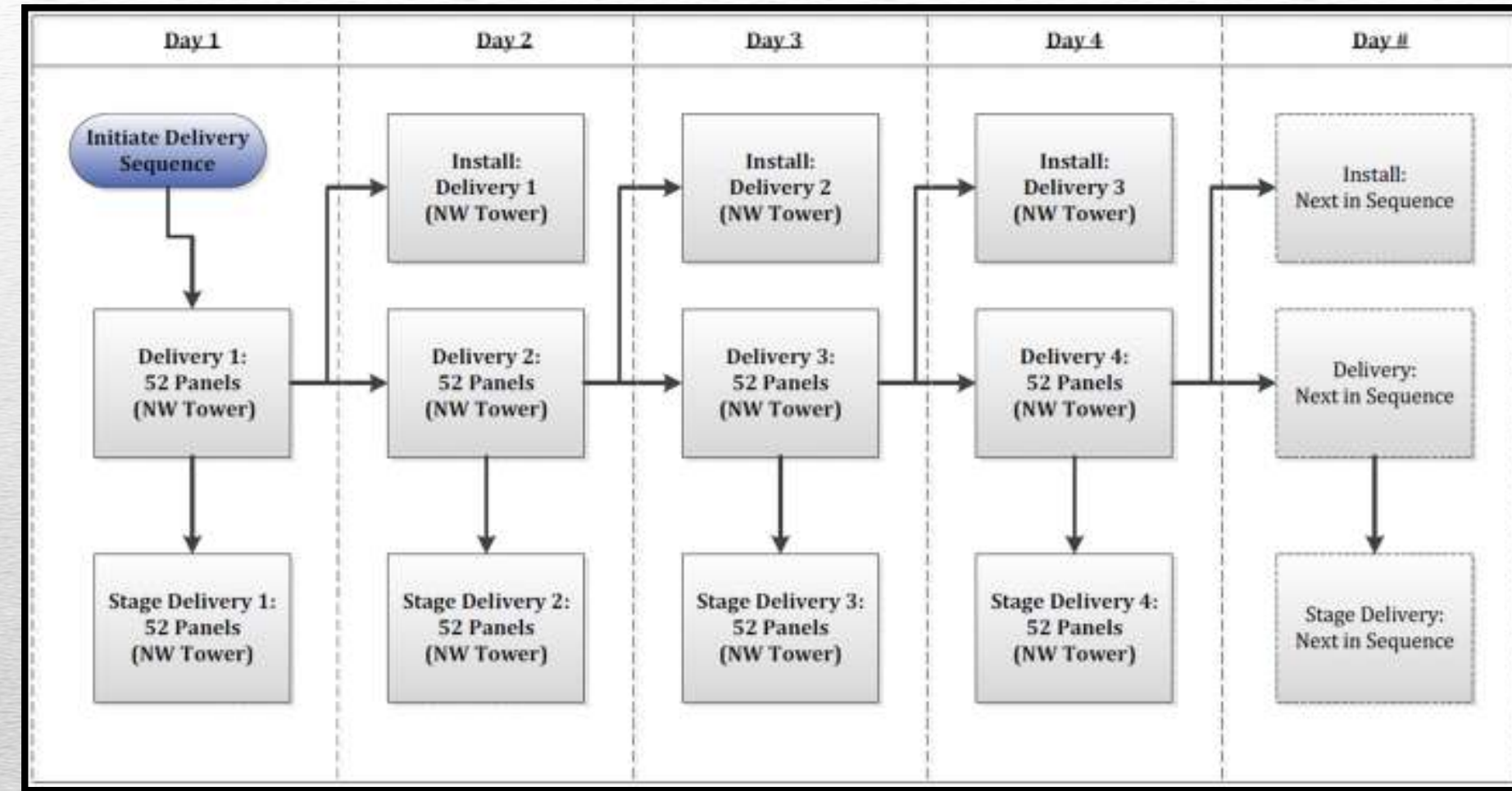
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- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES**
  - IV. RESULTS
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

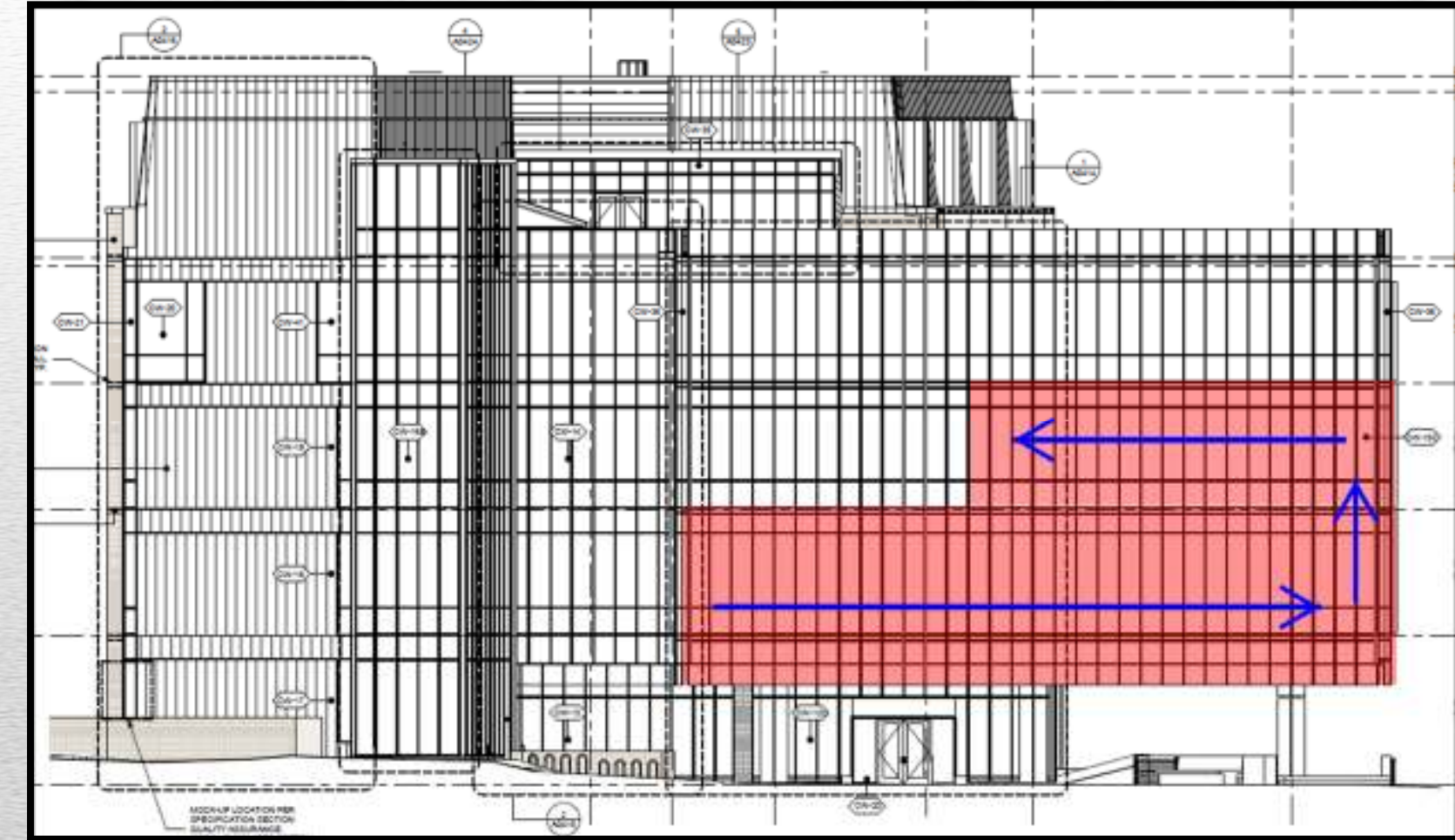
## Lean Principles

Unitized curtain wall panels implements a **pull production strategy**

Delivery sequence implements a **just-in-time** planning approach



Planning Process Map



Installation Sequence



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION
  - III. LEAN PRINCIPLES
  - IV. RESULTS**
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

## Results

### Unitized Curtain Wall Panel System

- Savings of \$612,014 to budget
- Accelerated schedule by 28 days
- Implementation of pull production just-in-time delivery to cut storage fees on-site and eliminate material handling times

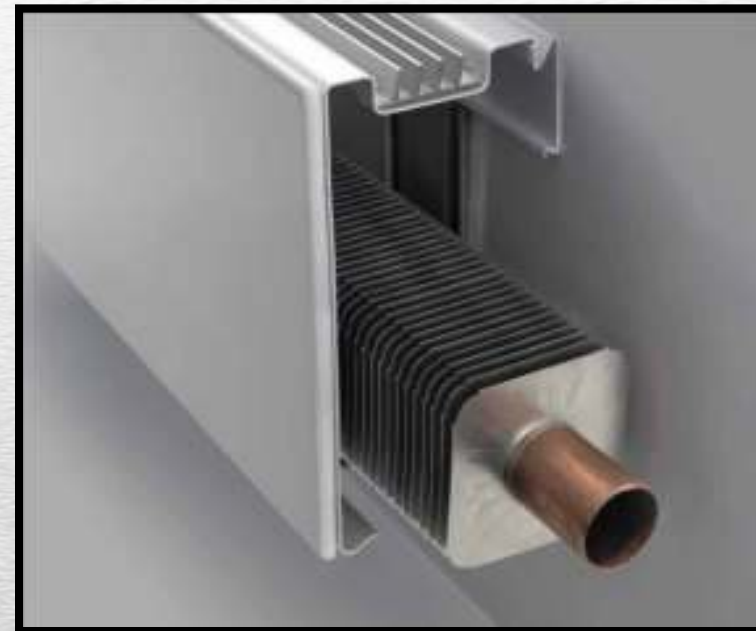
The constructability of the curtain wall system will be effectively increased through a unitized panel system. Time and costs will be saved due to decreased handling time and proper delivery sequences.





## OUTLINE

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN**
  - I. BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. RESULTS
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION



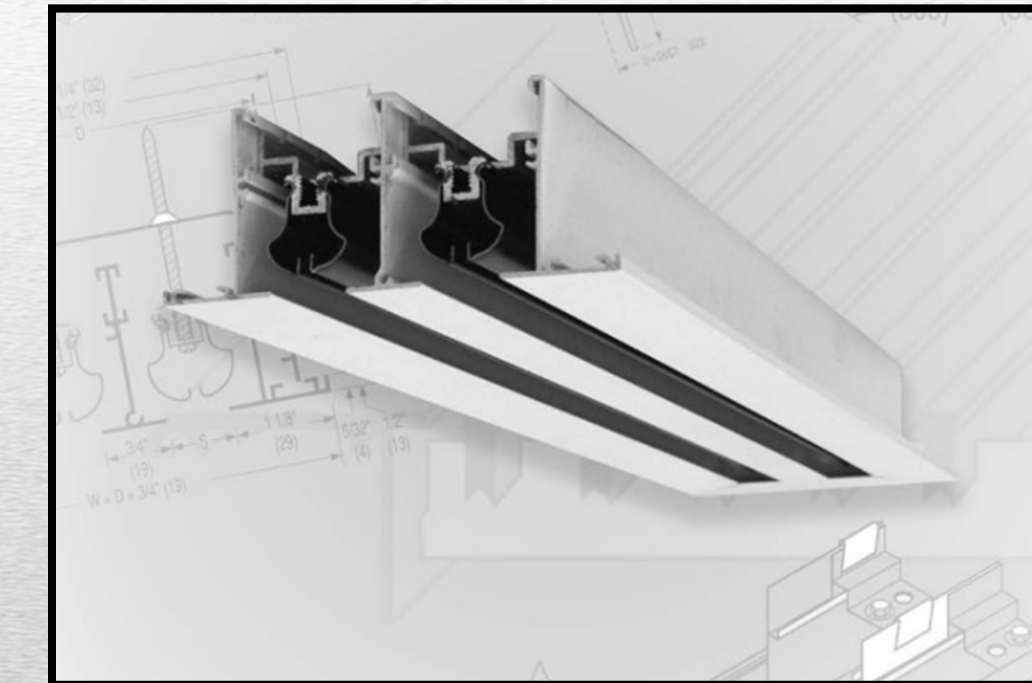
**Rittling Finned Tube Radiator**

## Problem Background

Finned tube radiators for perimeter heating leads to extended and cost prohibitive installation methods.

## Potential Solutions

Replace finned tube radiator units with linear diffusers at ceiling to provide same temperature air at perimeter as room air.



**Nailor Linear Diffuser**



## OUTLINE

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN**
  - I. BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. RESULTS
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

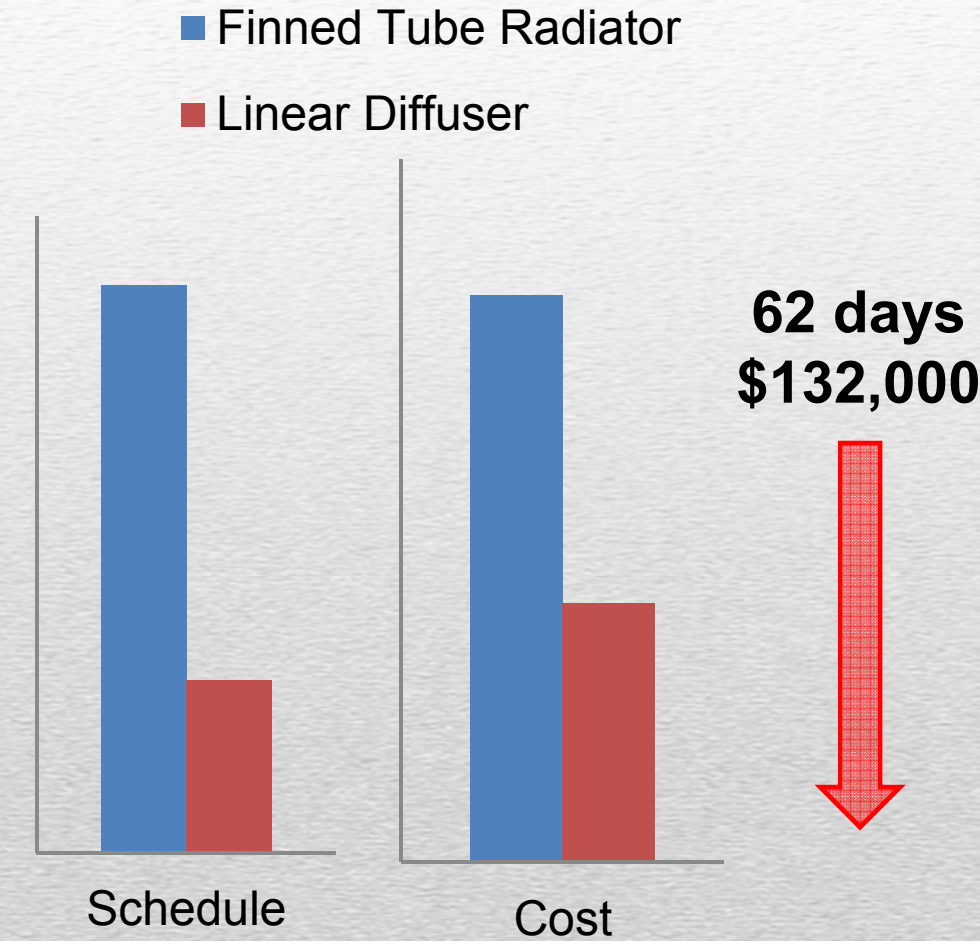
## Mechanical Breadth

- Finned tube radiator load in BTU/HR was converted to equivalent load in CFM
- Each equivalent CFM load was assigned to specific AHU based on location in building
- New linear diffuser duct run was sized appropriately for calculated CFM load
- Key assumption: Current duct sizes would not change due to the design alternative to add linear diffusers
  
- Goal: To determine the load savings on boiler and the additional load on air handling units



### OUTLINE

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION**
  - III. RESULTS
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION



## Schedule Evaluation

Item	Daily Output	Duration Per Crew	Crew No.	Total Duration (w/ Crews)
<b>Finned Tube Radiator System</b>				
Pipe Insulation	160	28.35	1	29.77
Insulation Waste (5%)	160	1.42		
Fittings (add 15%)	65	10.46	2	37.51
3/4" Copper Pipe	76	34		
1" Copper Pipe	68	19.31		
1-1/4" Copper Pipe	58	9.5		
2" Copper Pipe	42	0.86		
2-1/2" Copper Pipe	62	0.89		
Hydronic Pump, 3HP	5	0.4	1	0.4
FTR Units	38	40.79	2	20.395
<b>Total Duration for Finned Tube Radiator System</b>				<b>89</b>
<b>Linear Diffuser System</b>				
Aluminum Ductwork	145	41.7	2	26.385
Linear Diffusers	14	11.07		
<b>Total Duration for Linear Diffuser System</b>				<b>27</b>

## Cost Evaluation

Finned Tube Radiator System

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Pipe Insulation	4536	S.F.	\$ 10.12	\$ 2,297.24
Fittings (add 15%)	680	L.F.	\$ 26.65	\$ 18,122.00
3/4" Copper Pipe	2584	L.F.	\$ 16.05	\$ 41,473.20
1" Copper Pipe	1313	L.F.	\$ 20.45	\$ 26,850.85
1-1/4" Copper Pipe	551	L.F.	\$ 26.65	\$ 14,684.15
2" Copper Pipe	36	L.F.	\$ 46.50	\$ 1,674.00
2-1/2" Copper Pipe	55	L.F.	\$ 66.50	\$ 3,657.50
Insulation Waste (5%)	227	L.F.	\$ 10.12	\$ 2,297.24
Hydronic Pump	2	Ea.	\$ 4,234.00	\$ 8,468.00
FTR Units	1550	L.F.	\$ 79.00	\$ 122,450.00
<b>Total</b>				<b>\$ 241,974.18</b>

Linear Diffuser System

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
Aluminum Ductwork	6046	Lb.	\$ 14.93	\$ 90,266.78
Linear Diffusers	155	Ea.	\$ 130.00	\$ 20,150.00
<b>Total</b>				<b>\$ 110,416.78</b>



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION
  - III. RESULTS**
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION

## Results

### Linear Diffuser System Alternative

- Savings of \$132,000 to budget
- Accelerated schedule by 62 days
- Labor-intensive connections eliminated
- **Mechanical Breadth Outcome**
  - Savings of 358,000 BTU/HR on boiler
  - Increase of 8162 CFM, 2426 CFM & 5977 CFM on AHU 1, 2 & 3, respectively

The constructability of the alternative perimeter heating system will eliminate the labor-intensive brazing connections and costly copper hydronic piping. The linear diffusers are much more time effective and save on material cost.

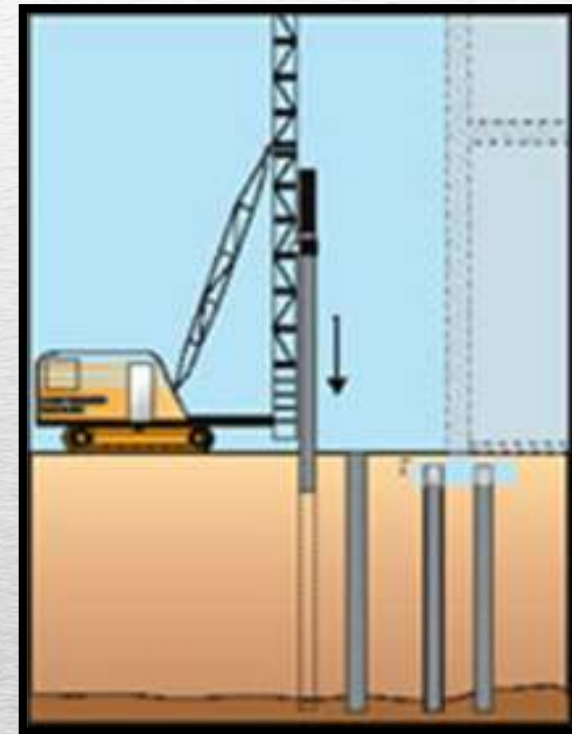
## Summary

Item	Finned Tube Radiator	Linear Diffuser	Difference
Cost (\$)	\$ 241,974.18	\$ 110,416.78	~ \$ 132,000
Schedule (Days)	89	27	62



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM**
  - I. BACKGROUND & SOLUTIONS**
  - II. SCHEDULE/COST EVALUATION
  - III. RESULTS
- VII. CONCLUSION



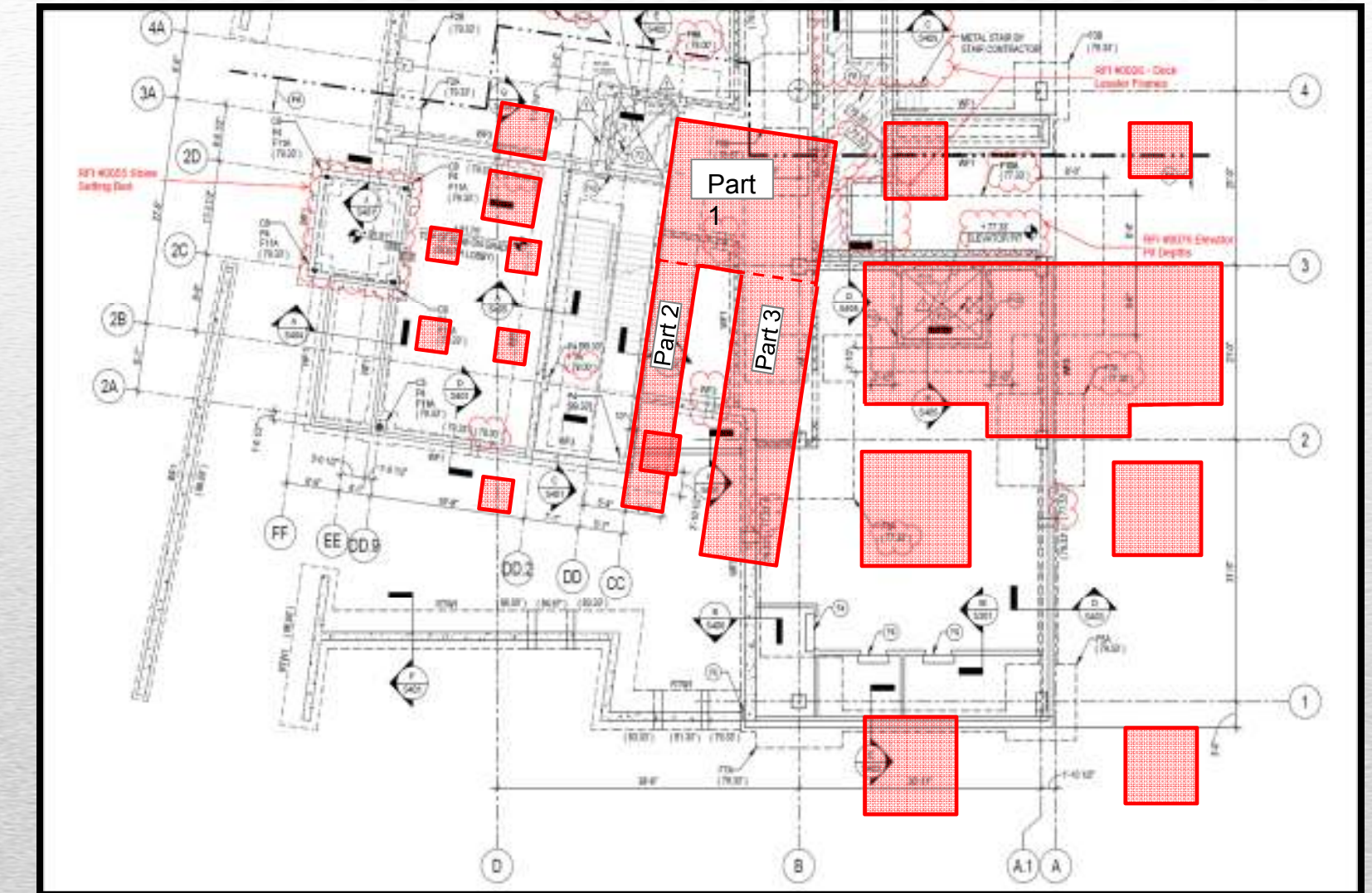
Driven Steel H-Pile Illustration

**Problem Background**

Potential schedule acceleration areas by analyzing an alternative foundation system in lieu of the current rammed aggregate piers

**Potential Solutions**

Replace rammed aggregate pier system with a driven steel H-pile system to reduce schedule duration and cost



Spread Footing Locations



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION**
  - III. RESULTS
- VII. CONCLUSION

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Design Capacities

**Schedule Evaluation**

Item	Quantity	Unit	Daily Output (V.L.F)	Total Duration (days)
<b>Driven Steel H-Piles</b>				
HP12x 53	2079	V.L.F.	590	3.52
HP12x 84	513	V.L.F.	590	0.87
Mob./Demob.	5184	V.L.F.	3300	1.57
<b>Total</b>				<b>6</b>
<b>Geopier System ( Based upon Bid Package #1)</b>				
				<b>10</b>
<b>Variance</b>			<i>(Savings)</i>	<b>(4)</b>

**Cost Evaluation**

Item	Quantity	Unit	Total Incl. O&P	Extended Total Incl. O&P
<b>Driven Steel H-Piles</b>				
HP12x 53	2079	V.L.F.	\$ 41.58	\$ 86,444.82
HP12x 84	513	V.L.F.	\$ 54.31	\$ 27,861.03
Mob./Demob.	5184	V.L.F.	\$ 1.98	\$ 10,264.32
<b>Total</b>				<b>\$ 124,570.17</b>
<b>Geopier System ( Based upon Bid Package #1)</b>				
				<b>\$ 150,000.00</b>
<b>Variance</b>			<i>(Savings)</i>	<b>\$ (25,429.83)</b>



**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM**
  - I. BACKGROUND & SOLUTIONS
  - II. SCHEDULE/COST EVALUATION
  - III. RESULTS**
- VII. CONCLUSION

## Results

### Driven Steel H-Pile Alternative

- Savings of \$25,000 to budget
- Accelerated schedule by 4 days
- Quality Assurance improved

The alternative driven pile system resulted in a lower cost due to the shallow depth of piles. The quality control issues are minimized due to the controllable characteristics of a steel member.

✓ Goal Achieved



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- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
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- VII. CONCLUSION**

**Final Summary**

- Overall savings of **94 days** in the schedule and a total of **\$769,000**

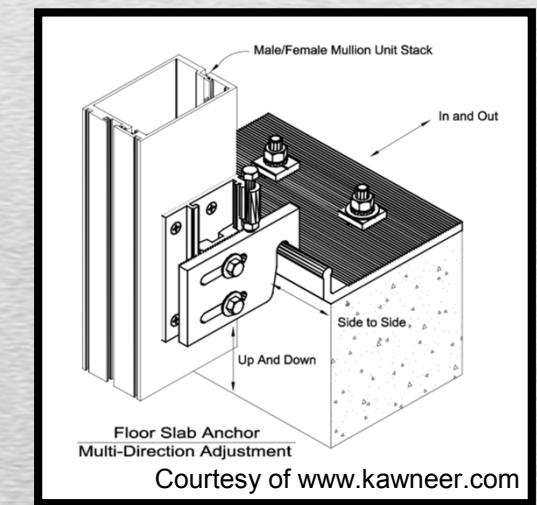
ANALYSIS 1 | SCHEDULE RESEQUENCE



- Replacing exterior cladding to brick veneer is cost prohibitive
- Last Planner System improves effective communication and can reduce accident frequency by 66%

ANALYSIS 2 | MODULARIZATION OF CURTAIN WALL

- Unitized panels saves \$612,014
- Accelerates schedule by 28 days
- Constructability of curtain wall greatly improves with pull production



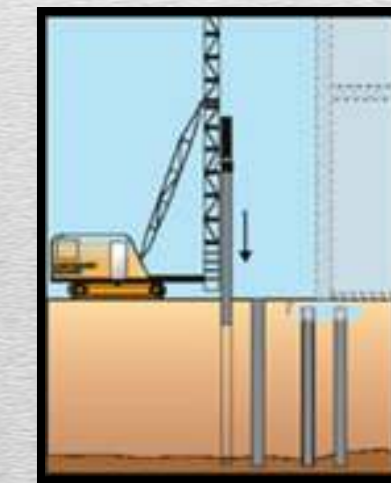
ANALYSIS 3 | FINNED TUBE RADIATOR DESIGN



- Linear diffuser alternative saves \$132,000
- Accelerates schedule by 62 days
- Eliminates on-site labor-intensive brazing connections and costly copper pipe

ANALYSIS 4 | ALTERNATIVE FOUNDATION SYSTEM

- Driven steel H-piles alternative saves \$25,000
- Accelerates schedule by 4 days
- Quality Assurance improved





**OUTLINE**

- I. INTRODUCTION
- II. PROJECT OVERVIEW
- III. ANALYSIS 1: SCHEDULE RESEQUENCE
- IV. ANALYSIS 2: MODULARIZATION OF CURTAIN WALL
- V. ANALYSIS 3: FINNED TUBE RADIATOR DESIGN
- VI. ANALYSIS 4: ALTERNATIVE FOUNDATION SYSTEM
- VII. CONCLUSION**

# Thank You!

## Special Thanks

The Barton Malow STC Project Team

My Family and Friends

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 Dr. Robert Leicht  
 Prof. Kevin Parfitt  
 Prof. Robert Holland  
 Penn State AE Faculty



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 Cannon Design  
 The University of Maryland  
 Coppin State University









# APPENDIX A – ANALYSIS 1

Analysis 1 - Exterior Envelope Estimate  
 Year 2013 Quarter 1  
 Unit Detail Report

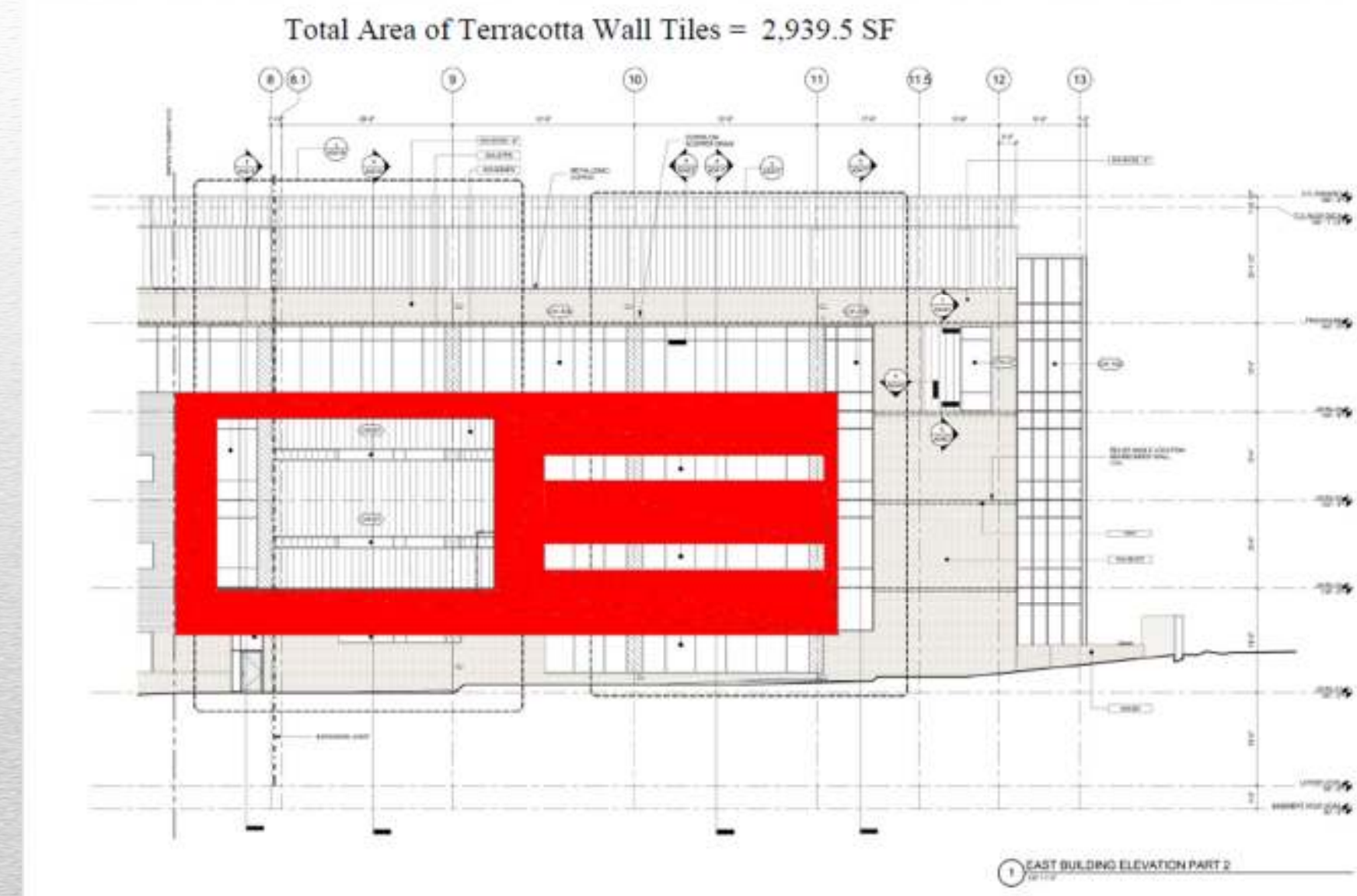
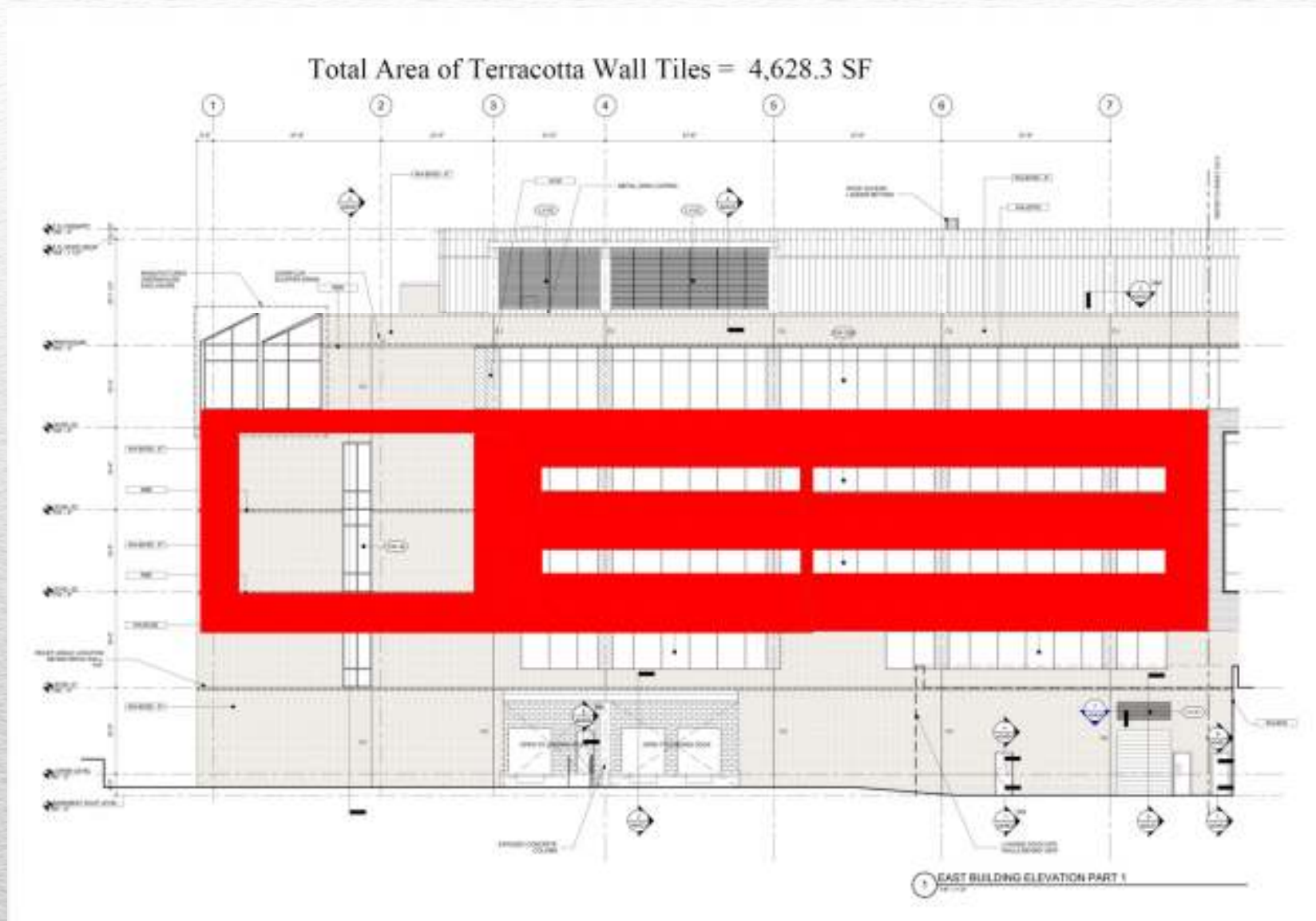
Prepared By:  
 Nick Zitterbart  
 PSU

LineNumber	Description	Quantity	Unit	Daily Output*	Total Incl. O&P*	Ext. Total Incl. O&P
<b>Division 04 Masonry</b>						
042113132020	Brick veneer masonry, red brick, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	7,567.80	S.F.	660	\$26.54	*\$200,849
042129200300	Terra cotta tile, dry set, square/hexagonal/lattice shapes, glazed, intense colors, 1/2" thick, on walls, includes mortar, excludes scaffolding	7,567.80	S.F.	390	\$14.97	*\$113,290

Difference: \$87,559 (add)  
 \*Adjusted for 3 working crews

Total Duration with upgraded crews:

Terracotta Tiles = 20 days  
 Brick Veneer = 12 days





## APPENDIX B – ANALYSIS 2

Curtain Wall Panels				
Location	Size	SF	No. Panels	Total SF
CW 15A	2' - 7-1/2" x 15'-4"	40.25	25	1006.25
Cw 15A	2' - 7-1/2" x 21'-4"	56	50	2800
CW 36	1'-8" x 18'-10"	31.4	3	94.2
CW 15B	2' - 7-1/2" x 15'-4"	40.25	32	1288
CW 15B	2' - 7-1/2" x 20'-4"	53.4	64	3417.6
CW 15C	2' - 7-1/2" x 15'-4"	40.25	32	1288
CW 15C	2' - 7-1/2" x 20'-4"	53.4	64	3417.6
CW 15D	2' - 7-1/2" x 15'-4"	40.25	12	483
CW 15D	2' - 7-1/2" x 20'-4"	53.4	24	1281.6
CW 1	3'-0" x 15'-4"	46	3	138
CW 2A	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 2B	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 3	2' - 7-1/2" x 20'-0"	52.5	5	262.5
CW 4	2' - 7-1/2" x 15'-4"	40.25	4	161
CW 4	2' - 7-1/2" x 18'-0"	47.25	8	378
CW 6A	2' - 7-1/2" x 15'-4"	40.25	8	322
CW 6A	2' - 7-1/2" x 11'-4"	29.75	4	119
CW 6A	2' - 7-1/2" x 18'-0"	47.25	4	189
CW 6B	2' - 7-1/2" x 15'-4"	40.25	20	805
CW 6B	2' - 7-1/2" x 11'-4"	29.75	10	297.5
CW 6B	2' - 7-1/2" x 18'-0"	47.25	10	472.5
CW 7	2' - 7-1/2" x 15'-4"	40.25	4	161

CW 10	2' - 7-1/2" x 15'-4"	40.25	18	724.5
CW 11	2' - 7-1/2" x 15'-4"	40.25	9	362.25
CW 11	2' - 7-1/2" x 12'-4"	32.36	9	291.24
CW 13	2' - 7-1/2" x 16'-9"	44	11	484
CW 14	2' - 7-1/2" x 16'-9"	44	27	1188
CW 12A	2' - 7-1/2" x 14'-6"	38.06	27	1027.62
CW 12B	2' - 7-1/2" x 14'-6"	38.06	17	647.02
CW 12C	2' - 7-1/2" x 14'-6"	38.06	8	304.48
CW 16A	2' - 7-1/2" x 14'-8"	38.5	9	346.5
CW 16A	2' - 7-1/2" x 15'-4"	40.25	36	1449
CW 16B	2' - 7-1/2" x 14'-8"	38.5	5	192.5
CW 16B	2' - 7-1/2" x 15'-4"	40.25	20	805
CW 16C	2' - 7-1/2" x 14'-8"	38.5	4	154
CW 16C	2' - 7-1/2" x 15'-4"	40.25	16	644
CW 17, 18, 19	2' - 7-1/2" x 11'-4"	29.75	3	89.25
CW 41	4' - 10" x 12'-4"	59.6	1	59.6
CW 20	8' - 6" x 12'-4"	104	1	104
CW 21	1' - 9" x 15'-4"	26.83	4	107.32
CW 22	5' - 4" x 14'-9"	78.66	1	78.66
CW 23A	1' - 2-1/2" x 15'-4"	18.5	4	74
CW 23B	6' - 2-3/4" x 15'-4"	95.5	4	382

CW 24	5'-3" x 7'-0"	36.75	9	330.75
CW 25	5'-3" x 4'-6"	23.63	9	212.67
CW 25A	5'-3" x 4'-6"	23.63	9	212.67
CW 29	3'-0" x 15'-4"	46	4	184
CW 30A	5'-3" x 11'-8"	61.2	24	1468.8
CW 30B	5'-3" x 11'-8"	61.2	28	1713.6
CW 31	5'-3" x 7'-0"	36.75	11	404.25
CW 33	5'-3" x 7'-0"	36.75	10	367.5
CW 32	5'-3" x 4'-6"	23.63	21	496.23
CW 34	2' - 7-1/2" x 15'-4"	40.25	6	241.5
CW 35	2' - 7-1/2" x 11'-6"	30.12	14	421.68
<b>Totals</b>			<b>783</b>	<b>34675</b>

Cost Estimate			
	Cost/SF	SF	Total
Stick-Built	\$ 180.00	34675	\$ 6,241,500.00
Panel - Wausau 7250-UW	\$ 153.00	34675	\$ 5,305,275.00
Staging Crew	\$ 9.35	34675	\$ 324,211.25
		Variance	\$ 5,629,486.25



# APPENDIX C – ANALYSIS 3

Analysis 3 - Finned Tube Radiation System  
Year 2013 Quarter 1  
Unit Detail Report

Prepared By:  
Nick Zitterbart  
PSU

LineNumber	Description	Quantity	Unit	Daily Output	Total Incl. O&P	Ext. Total Incl. O&P
<b>Division 22 Plumbing</b>						
22071910000	Insulation waste, 5%	227.00	L.F.		\$10.12	\$2,297.24
220719107813	Insulation, pipe covering (price copper tube one size less than I.P.S.), finishes, .010" thick, for stainless steel jacket, add	4,536.00	S.F.	160.00	\$10.12	\$45,904.32
221113230000	Fittings add 15% of pipe, based on 4536' pipe	680.00	L.F.		\$26.65	\$18,122.00
221113232180	Pipe, copper, tubing, solder, 3/4" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	2,584.00	L.F.	76.00	\$16.05	\$41,473.20
221113232200	Pipe, copper, tubing, solder, 1" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	1,313.00	L.F.	68.00	\$20.45	\$26,830.85
221113232220	Pipe, copper, tubing, solder, 1-1/4" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	551.00	L.F.	58.00	\$26.65	\$14,684.15
221113232260	Pipe, copper, tubing, solder, 2" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	36.00	L.F.	42.00	\$46.50	\$1,674.00
221113232280	Pipe, copper, tubing, solder, 2-1/2" diameter, type L, includes coupling & clevis hanger assembly 10' O.C.	55.00	L.F.	62.00	\$66.50	\$3,657.50
<b>Division 22 Plumbing Subtotal</b>						<b>\$154,663.26</b>

**Division 23 Heating, Ventilating, and Air Conditioning (HVAC)**

232123131180	Pump, circulating, bronze, heated or chilled water application, in line, flanged joints, 1/4 H.P., 2-1/2" size	2.00	Ea.	5.00	\$4,234.00	\$8,468.00
238236101200	Hydronic heating, terminal units, fin tube, wall hung, 14" slope top cover, 1-1/4" copper tube, 4-1/4" aluminum fins, includes damper, excludes main supply pipe	1,550.00	L.F.	38.00	\$79.00	\$122,450.00

**Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal**

**\$130,918.00**

**TOTAL: \$285,581.26**

Cost Effect on Boiler with reduced load:

Total decreased load from eliminating FTR = 358 MBH

Existing Boiler (B-3 = 3000MBH capacity) = \$47,600 (Total O&P)

Installation Time = 179MH

New Boiler (2856 MBH) = \$44,100 (Total O&P)

Installation Time = 160MH



# APPENDIX C – ANALYSIS 3

Analysis 3 - Linear Diffusers  
Year 2013 Quarter 1  
Unit Detail Report

Prepared By:  
Nick Zitterbar  
PSU

LineNumber	Description	Quantity	Unit	Daily Output	Total Incl. O&P	Ext. Total Incl. O&P
<b>Division 23 Heating, Ventilating, and Air Conditioning (HVAC)</b>						
233113130160	Metal ductwork, fabricated rectangular, over 5000 lb., aluminum alloy 3003-H14, includes fittings, joints, supports and allow for a flexible conn. field sketches, excludes as-built dwgs. and insul.	6,046.00	Lb.	145.00	\$14.93	\$90,266.78
233713101040	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 12" x 9", includes opposed blade damper	155.00	Ea.	14.00	\$130.00	\$20,150.00
<b>Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal</b>						<b>\$110,416.78</b>

Cost Effect on AHU with increased load:

Total increased load - AHU1 = 8162CFM, AHU2 = 2426CFM, AHU3 = 5977CFM

Existing AHU1 (23500CFM) = \$41,975 (Total O&P), Installation Time = 40MH

Existing AHU2 (33000CFM) = \$65,875 (Total O&P), Installation Time = 80MH

Existing AHU3 (44500CFM) = \$65,875 (Total O&P), Installation Time = 80MH

New AHU1 (31700CFM) = \$65,875 (Total O&P), Installation Time = 80MH

New AHU2 (35500CFM) = \$65,875 (Total O&P), Installation Time = 80MH

New AHU3 (50500CFM) = \$80,480 (Total O&P), Installation Time = 104 MH (extrapolation)

Variance:

AHU1 -> add \$23,900 and 40MH

AHU2 -> no change

AHU3 -> \$14,605 and 24MH

BTU/HR coversion to CFM to evaluate additional load on AHU's

$q=1.08CFM\Delta T$ , where  $\Delta T = 75-55 = 20$  and  $q$  is BTU/HR totals listed above

	Increased Load on AHU	Dec. on Boiler
	CFM	MBH
AHU-1	8162	176
AHU-2	2426	52
AHU-3	5977	129
<b>Total</b>	<b>16565</b>	<b>358</b>

Duration to install FTR 3 per steamfitter per day
<b>Total FTR</b> 155

Linear diffusers Total of 155 added Average of 15' of round duct necessary per diffuser based on plans duct size determined by above CFm per diffuser
--



## APPENDIX C – ANALYSIS 3

Summary - Round Duct Size and Weights (24G)					
Duct Size (in.)	Qty (@15LF)	Tot LF	SA(ft2/ft)	Weight (24G)	Tot Weight (lb)
5	3	45	1.31	1.67	75.15
6	9	135	1.57	1.98	267.3
7	51	765	1.83	2.3	1759.5
8	11	165	2.09	2.61	430.65
9	12	180	2.36	2.93	527.4
10	2	30	2.62	3.34	100.2
12	1	15	3.14	3.97	59.55
				<b>TOTAL WEIGHT</b>	<b>3220</b>
				(Fittings, Turns) 10%	<b>3542</b>

FTR Piping QTO Summary			
WBS	Description	Quantity 1	
1" PHWR	Copper	452.12	ft
1" PHWS	Copper	860.74	ft
1-1/4" PHWR	Copper	312.61	ft
1-1/4" PHWS	Copper	238.39	ft
2" PHWR	Copper	35.58	ft
2-1/2" PHWR	Copper	55.10	ft
3/4" PHWR	Copper	1,150.08	ft
3/4" PHWS	Copper	1,434.09	ft



# APPENDIX D – ANALYSIS 4

## Analysis 4 Supplemental Work Driven Pile Calculations

Footing: 4A-EE

Type: F2B      Size: 6'-0" x 6'-0" x 1'-10"

Reinf: 10-#6 Each Way Bottom

H-Pile Size	Allow. Capacity (kips)
12x53	390
12x84	620
14x117	860

Bearing Capacity: 14000 PSF (P= 504k)

Per Geotech Report: Spacing  $\geq$  3D, D = Dia. Of Pile

Spacing Parallel to P	Ded. Factor
$\geq 8D$	1
6D	0.8
4D	0.5
$\leq 3D$	0.4

Choose Pile Type: 12x 53 → D= 12in and Bearing Capacity = 390 k

3D= 36 in.  
Cover<sub>min</sub> = 9 in.  
 $d_{min} = \text{Cover}_{min} + D/2 = 1.25'$   
L= 6' [Per S001]  
B= 6' [Per S001]

### B Direction

$S_B = B - 2*d_{min} = 3.5'$   
 $N_B < S_B/3D \rightarrow N_B < 1.167$   
 $N_B > S_B/10' \rightarrow N_B > 0.35$

So  $N_B = 1$       Two rows in 'B' direction

### L Direction

$S_L = L - 2*d_{min} = 3.5'$   
 $N_L < S_L/3D \rightarrow N_L < 1.167$   
 $N_L > S_L/10' \rightarrow N_L > 0.35$

So  $N_L = 1$       Two rows in 'L' direction

P = 504k (from column)

$P_{\text{reaction, H pile}} = 390 * 0.4$  (reduction factor) = 156k

$P_{\text{reaction, H pile total}} = 156k * 4 = 624k$

Is  $P_{\text{reaction, H pile total}} > P$ ?      Yes, therefore okay

**4 - 12x53 Piles @ 27' will support this footing**

Note: 27' is depth to bedrock per geotech report

### Analysis 4 - Drive Steel H Piles Year 2013 Quarter 1 Unit Detail Repor

Prepared By:  
Nick Zitterbart  
PSU

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
<b>Division 31 Earthwork</b>					
316216130700	Steel piles, "H" Sections, 50' long, HP12 x 53, excludes mobilization or demobilization	2,079.00	V.L.F.	\$41.58	\$86,444.82
316216130800	Steel piles, "H" Sections, 50' long, HP12 x 74, excludes mobilization or demobilization	513.00	V.L.F.	\$54.31	\$27,861.03
316219102700	Timber piles, treated wood pile, mobilization, for 10,000 L.F. pile job	5,184.00	V.L.F.	\$1.98	\$10,264.32
<b>Division 31 Earthwork Subtotal</b>					<b>\$124,570.17</b>

Note: HP12x74 were used in placed of HP12x84 for calculations based on availability in Reed Construction Data  
Mobilization/Demobilization costs for timber and steel piles are the same per Reed Construction Data  
Daily Output: H-Piles - 590 V.L.F, Mob/Demob - 3300 V.L.F



## APPENDIX D – ANALYSIS 4

Footing Location (Column Lines)	Footing Type (Per S100)	Footing Size (Per S100)	Pile Type	Qty. of Pile (27' length)
4A-EE	F2B	6'-0" x 6'-0" x 1'-10"	HP12x 53	4
3A-EE	F2A	6'-0" x 6'-0" x 1'-2"	HP12x 53	4
2D-FF, 2D-DD.9, 2C-FF, 2C-DD.9	F11A	4'-0" x 4'-0" x 1'-0"	HP12x 53	16 (4 ea.)
2A-DD.9	F11A	4'-0" x 4'-0" x 1'-0"	HP12x 53	1
2B-DD.2	F1A	5'-0" x 5'-0" x 1'-0"	HP12x 53	1
4A-DD	F9A (Part 1)	15'-0" x 16'-0" x 3'-0"	HP12x 53	12
4A-DD	F9A (Part 2)	30'-0" x 4'-0" x 3'-0"	HP12x 53	5
4A-DD	F9A (Part 3)	32'-0" x 9'-0" x 3'-0"	HP12x 53	12
4-B	F5B	9'-0" x 9'-0" x 2'-8"	HP12x 53	9
4-A.1	F3B	7'-0" x 7'-0" x 2'-4"	HP12x 84	4
3-B to A	F10A	42'-0" x 17'-0" x 4'-0"	HP12x 84	15
2-B	F8A	14'-0" x 14'-0" x 3'-0"	HP12x 53	9
2-A.1	F7A	11'-0" x 11'-0" x 2'-4"	HP12x 53	6
1-A.1	F5A	9'-0" x 9'-0" x 1'-10"	HP12x 53	4
1-B	F7A	11'-0" x 11'-0" x 2'-4"	HP12x 53	6
<b>Totals</b>				
			<b>HP12x 53</b>	<b>77</b>
			<b>HP12x 84</b>	<b>19</b>