

900 16th Street NW



Douglas Watson
Advisor – Rob Leicht

Architectural Engineering Senior Thesis
Construction Management Option

900 16th Street NW

Presentation Outline

- Project Background
- Analysis 1: Modular Concrete Formwork
 - Introduction and Background
 - Formwork System and Implementation
 - Schedule Analysis
 - Cost Analysis
- Analysis 2: Exterior Façade System Redesign
 - Structural Breadth
 - Mechanical Breadth
- Analysis 3: Driving Collaboration with Lean Construction
- Analysis 4: Prismatic Curtainwall Glazing Units
- Recommendations
- Conclusion

Project Background

Building Information

Location: Washington DC
Size: 200,000 SF
Stories: 12
Project Delivery: Negotiated CM at Risk
w/ GMP
Cost: \$38,000,000
Construction Dates: February 2014 –
March 2016



Project Team

Owner: Undisclosed
Architect: Robert AM Stern & Cooper Carry
GC: James G. Davis Construction
MEP Engineer: Dewberry
Structural Engineer: Thornton-Tamasetti



[Images courtesy of DAVIS]



[Images courtesy of DAVIS]

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Analysis 1: **Modular Concrete Formwork**

Analysis Background

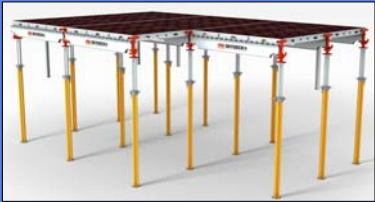
Problem	- Stick-Built formwork is time consuming and requires a large labor force
Proposed Solution	- Implementation of modular formwork
Goals	- Reduction in duration of Cast-in-Place Structure - Reduction in required man power - Increase ease of installation

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Formwork Systems



Peri Sky Deck

- Modular System
- Aluminum posts and tables
- Erection Rate: 25 SF/Man hour
- Used in flat spans

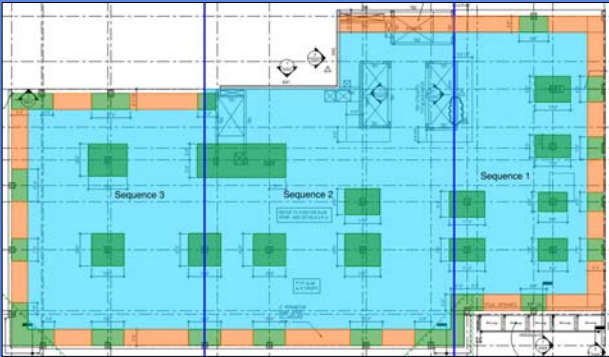
Peri Multiflex

- Post & Beam System
- Erection Rate: 18 SF/Man hour
- Used at drop panels



[Images courtesy of Peri-USA.com]

Typical Slab Forming Sequencing



[Images courtesy of Cooper Carry]

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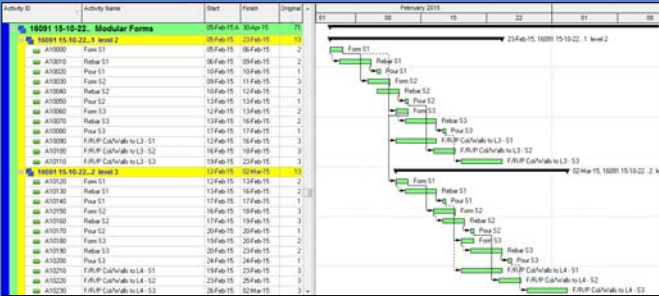
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Schedule Analysis

Production Rates - Alternative Formwork							
Sequence	System	Qty	Unit	Production Rate (LH/SF)	Required LH	Required Days	Total Days with overlapping crew work
1	Multiflex	Forms	1533	SF	0.055	84.315	2
	Plywood	1533	SF	0.011	16.863	0.85	
	Sky Deck	Forms	2912	SF	0.04	116.48	
2	Multiflex	Forms	1258	SF	0.055	69.19	3
	Plywood	1258	SF	0.011	13.838	0.7	
	Sky Deck	Forms	5538	SF	0.04	221.52	
3	Multiflex	Forms	1950	SF	0.055	107.25	2
	Plywood	1950	SF	0.011	21.45	1.07	
	Sky Deck	Forms	3435	SF	0.04	137.4	
Totals							7

Sample Schedule for CIP Structure



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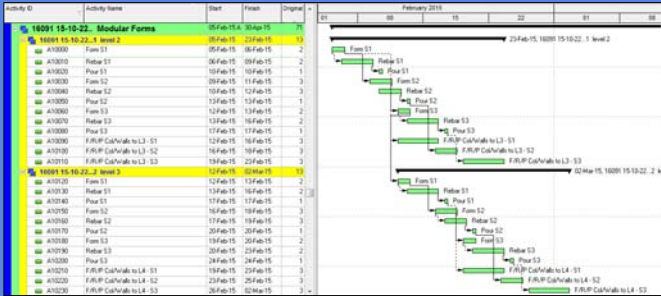
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Totals							7

Summary of Projected Schedule Savings			
Formwork System	Sequence Duration	Floor Duration	Total Duration
Stick-Built	4	18	91
Peri Systems	2.3	13	71
Difference	1.7	5	20

22% Reduction

Sample Schedule for CIP Structure



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Cost Analysis

Formwork Rental

Sky Deck - \$1.85 per SF per month
Multiflex - \$1.18 per SF per month

Rental Costs & Plywood for Peri Systems					
System	Qty	Unit	Price/Unit/Month	Rental Cycles	Total Cost
Skydeck	23770	SF	\$ 1.85	3	\$131,923.50
Multiflex	9592	SF	\$ 1.15	3	\$ 33,092.40
Plywood	14388	SF	\$ 0.76	1	\$ 10,934.88

Total Cost

\$175,950.00

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Cost Comparison

Formwork System Cost Comparison			
System	Material Cost	Labor Cost	Total Including O&F
Stick-Built	\$ 10,934.00	\$ 623,018.00	\$ 792,442.04
Peri Systems	\$175,950.78	\$ 155,754.69	\$ 414,631.83
Difference	\$165,016.78	\$(467,263.31)	\$ (377,810.21)

Total Savings

\$377,810.21

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Analysis 2: Exterior Façade System Redesign



Analysis Background

Problem	Erection of precast façade system is time consuming
Proposed Solution	Implementation of an alternative façade system
Goals	Reduction in the installation duration Reduction of exterior façade system costs Increase ease of installation Improved thermal performance of exterior wall system

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Alternative Façade System

Prefabricated EIFS Panels with a Thermocromex finish

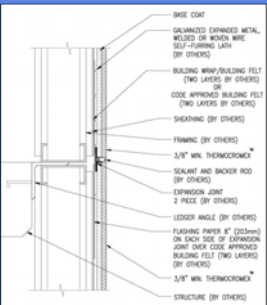
Benefits

- Most closely matches natural stone
- Lightweight (12lbs/SF)
 - Allows for larger panels
- Increased thermal performance
- High resistance to impact
- Significantly cheaper than limestone

Drawbacks

- Higher maintenance
- Contractors may not be familiar with product
- Issues with installation

Typical Prefab Panel Section



[Images courtesy of Thermocromex.com]

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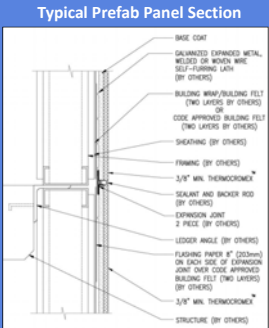
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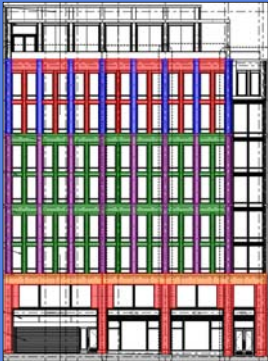
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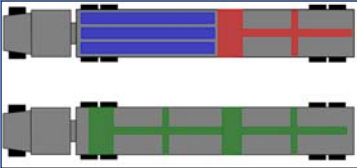
[Images courtesy of Thermocromex.com]

South Elevation Panel Breakdown



[Images courtesy of Construction Documents]

Panel Delivery Configuration



Prefabricated Panel Dimensions

- Green – 44'-6" x 8'-6"
- Purple – 44'-6" x 2'-2"
- Red – 24' x 8'-6"
- Blue – 24' x 2'-2"

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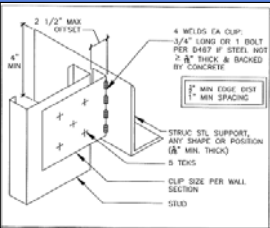
Original Façade Erection Rates

- Max rate of erection = 12 panels/day
- Average rate of erection = 8 panels/day

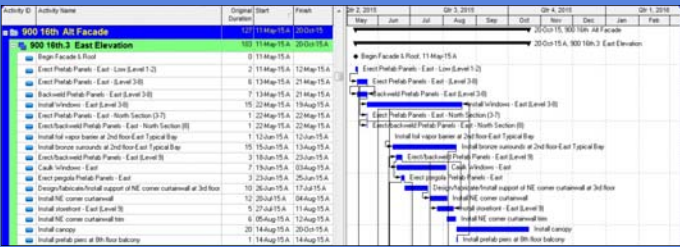
Alternative Façade Erection Rates

- Secondary erection crane (East)
 - 1 panel per hour
 - Average of 9 prefab panels/day
- Tower Crane (West and South)
 - Operating at 60%
 - 6 panels/day max

Connection Method



Sample Alternative Schedule



Façade System Schedule Comparison				
System	Elevation			Total
	East	South	West	
Original	121	119	105	141
Alternative	103	99	92	127
Difference	18	20	13	14

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Cost Analysis

Façade System Material Cost Comparison			
System	Qty (SF)	SF Cost	Total Cost
Precast Concrete w/Stone Veneer	16904.4	\$ 122.66	\$ 2,073,500.00
Prefabricated Thermocromex	16904.4	\$ 32.67	\$ 552,309.40

Original System

58% or \$1,324,000 comes from stone veneer



100 Ton Crane



60 Ton Crane

Façade System Erection Cost Comparison			
System	Labor Cost	Equipment Cost	Total Cost
Precast Concrete w/Stone Veneer	\$110,418.00	\$ 160,650.00	\$ 271,068.00
Prefabricated Thermocromex	\$ 92,015.00	\$ 105,455.00	\$ 197,470.00

Reduction in Erection Costs

\$73.598.00

[Images courtesy of Job Site Camera and www.manitowoccranes.com/]

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58% or \$1,324,000 comes from stone veneer

Total Cost Comparison

Savings of **\$1,593,712**

4% reduction in total contract value



100 Ton Crane



60 Ton Crane

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Structural Breadth: Column Load Analysis

Axial Load Analysis

Parameters:

- Column G3
- A_c = 372 SF
- f'c = 6,000 psi
- Total Dead Load = 45.72 kips
- Reduced Live Load = 23.04 kips

Calculations

Total Load = 91.72 kips/floor
Total Panel/Storefront load = 26.59 kips

Total axial load = 1,132 kips
Maximum allowable axial load = 1,453 kips

1,453 kips > 1,132 kips ✓

Moment Analysis

Parameters:

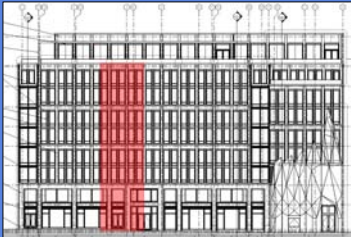
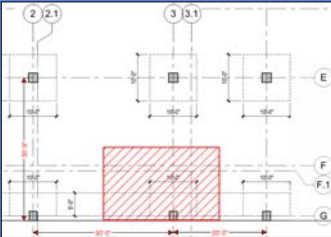
- Column G3 at Typical Floor
- f'c = 6,000
- Floor Height = 11' 2"

Calculations

Maximum applied moment = 187 in - kips
Max allowable moment = 2204 in - kips

2204 in -kips > 187 in - kips ✓

Tributary Area Definition



[Images courtesy of Cooper Carry]

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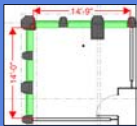
Mechanical Breadth

R-Value Summaries

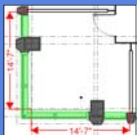
Precast Concrete with Stone Veneer	
Material	R-Value
5/8" GWB	0.57
3-5/8" Metal Stud	0.01
Vapor Barrier	0.12
3" Semi-Rigid Insulation	10.68
11" Precast Concrete	1.44
3" Limestone Veneer	0.18
TOTAL	13

Prefabricated Thermocromex Panels	
Material	R-Value
5/8" GWB	0.57
3-5/8" Metal Stud	0.01
Vapor Barrier	0.12
3" Semi-Rigid Insulation	10.68
6" Steel Studs (16 ga.)	0.02
1/2" GWB	0.56
Weather Barrier	0.17
Adhesive	0
2" EPS Insulation Board	10
Building Felt	0.06
Metal Lath	0
Base Coat	0.94
Thermocromex Finish Coat	
TOTAL	23.13

Level 5 Floor Plan



Office 0557



Office 0546

Room Characteristics					
Space	Exterior Wall	Length	Height	SF of Wall	% Window Coverage
Office 0557	West	14'-9"	11'-2 1/2"	165 SF	50%
	South	14'-0"	11'-2 1/2"	157 SF	50%
Office 0546	South	14'-7"	11'-2 1/2"	164 SF	68%
	East	14'-7"	11'-2 1/2"	164 SF	68%

[Images courtesy of Cooper Carry]

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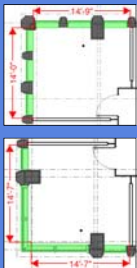
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Mechanical Breadth: Results

Cooling Load Comparison		
Applicable Loads	Cooling Coil Peak Load (BTU/hr)	
	Precast Concrete w/Stone Veneer	Prefabricated Thermocromex Panels
Envelope Loads		
Glass Solar	6831	6831
Glass/Door	436	436
Wall	654	368
Internal Loads		
Lights	701	701
People	500	500
Total	9122	8836

Required cooling load was reduced by **286 BTU/hr**

Monthly Utility Cost Comparison		
Month	Total Costs	
	Precast Concrete w/Stone Veneer	Prefabricated Thermocromex Panels
January	\$91.00	\$90.00
February	\$83.00	\$79.00
March	\$86.00	\$85.00
April	\$85.00	\$84.00
May	\$88.00	\$88.00
June	\$88.00	\$88.00
July	\$92.00	\$92.00
August	\$92.00	\$92.00
September	\$90.00	\$90.00
October	\$88.00	\$87.00
November	\$86.00	\$85.00
December	\$87.00	\$87.00
Total	\$1,056.00	\$1,047.00

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Analysis 3: **Driving Collaboration with Lean Construction**

Analysis Background

Problem	Poor communication between trades on site
Proposed Solution	Implementation lean construction methods focusing on Collocation and Last Planner
Goals	Improve contractor communication Create a collaborative workplace

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Colocation

What is Colocation?

- “Bringing key members of the project team together in close proximity under a single roof” – Tim Jones

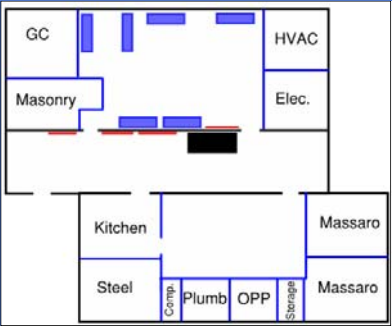
Benefits of Colocation

- Reduces number of written RFI's
- Increases understanding of trades scopes
- Creates the atmosphere for collaboration

What parties are included?

- All large trades
- Any trade with “non-working” superintendent

Sample Colocation Trailer Layout



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Colocation: Feasibility

900 16th Street Site



[Images courtesy of google maps and jobsite camera]

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Site Congestion



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Colocation: Feasibility

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Site Congestion



Alternative Colocation Location



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- Recommendations
- Conclusion

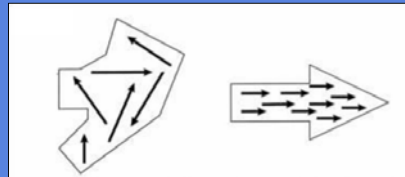
Last Planner

Advantages

- Early contractor involvement
- Highlights constraints
- Reliable workflow
- Increase in communication

Drawbacks

- Can be difficult to get contractor buy in
- Consistent schedule maintenance
- Over commitment of contractors



[Images courtesy of DAVIS]

Essential Steps of Last Planner

- ❑ Milestone Master Scheduling
- ❑ Phase Planning
- ❑ Look-Ahead Planning
- ❑ Weekly Work Plan
- ❑ Plus/Delta and Percent Plan Complete


900 16th Street NW

Presentation Outline

- Project Background
- Analysis 1: Modular Concrete Formwork
- Analysis 2: Exterior Façade System Redesign
- Analysis 3: Driving Collaboration with Lean Construction
 - Introduction and Background
 - Colocation
 - Last Planner
- Analysis 4: Prismatic Curtainwall Glazing Units
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Last Planner

Sample Weekly Work Plan

WEEKLY WORK PLAN															
												Date: 3/27/2014			
Area:	PS	CATEGORIES OF PLAN FAILURE										TOTAL ACTIVITIES			
Subcontractor:	AB	1 Coordination	3 Resource Work	9 Submittals	11 Issues							ACTIVITIES COMPLETED			
Build:	Day	2 Eng/Design	3 Labor	10 Approvals	14 Site Conditions							PERCENT PLANNED			
Use Planner:		3 Owner Decisions	2 Materials	11 Equipment	10 Inspections							COMPLETE			
		4 Weather	20 Construction	10 RFI	24 Other										
Planner:															
Schedule Activity:															
ID	ASSIGNMENT DESCRIPTION				Responsible Individual		Start Date		Finish Date		LEARNING		Comments		
	Sub: (Default) / Issue: / Project Sequence / Right Size / Mile to Start						Mon	Tue	Wed	Thu	Fri	Sat		SUN	REASONS FOR PLAN FAILURE
	Baseline pour 1 +				PDI										
	Layout, install elevators, drains, inserts pour 1				DEPTC										
	Install cables & bottom reinforcement pour 1				PBL										
	Install stand-off nuts pour 1				PDI										
	Install top reinforcement pour 1				PBL										
	Pour deck pour 1				PBL										
	Frame deck pour 2				PBL										
	Baseline pour 2				PDI										
	Layout, install elevators, drains, inserts pour 2				DEPTC										
	Install cables pour 2				PBL										
	Install bottom reinforcement pour 2				PBL										

[Images courtesy of DAVIS]

Essential Steps of Last Planner

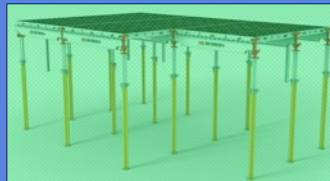
- ❑ Milestone Master Scheduling
- ❑ Phase Planning
- ❑ Look-Ahead Planning
- ❑ Weekly Work Plan
- ❑ Plus/Delta and Percent Plan Complete

900 16th Street NW

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Recommendations



Analysis 1: Modular Concrete Formwork

20 Days = 22% Reduction in schedule

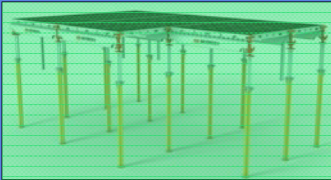
\$377,000 in cost savings

900 16th Street NW

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Recommendations



Analysis 1: Modular Concrete Formwork

20 Days = 22% Reduction in schedule

\$377,000 in cost savings



Analysis 2: Exterior Façade System Redesign

14 Days = 9% Reduction in schedule

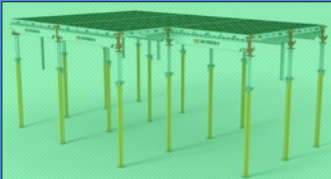
\$1.6 Million = 68% Reduction in cost

900 16th Street NW

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Recommendations



Analysis 1: Modular Concrete Formwork

20 Days = 22% Reduction in schedule

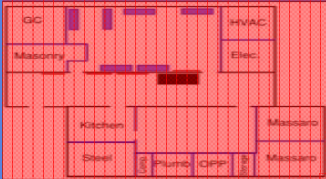
\$377,000 in cost savings



Analysis 2: Exterior Façade System Redesign

14 Days = 9% Reduction in schedule

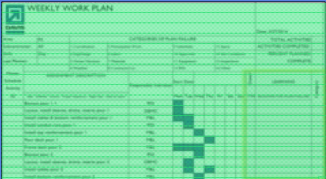
\$1.6 Million = 68% Reduction in cost



Analysis 3: Driving Collaboration with Lean Construction

Colocation – Unfeasible for the site conditions

Last Planner – Recommended



900 16th Street NW

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AE Faculty

Friends and AE classmates

