Baltimore Washington Medical Center
Women's Center and Inpatient Tower

Glen Burnie, MD

Megan Wortman
Construction Management
Spring 2008

Presentation Overview

- **Project Overview**
- **Analysis 1:** Precast Hollow Core Planks vs. Composite Slab
- **Analysis 2:** EIFS vs. GFRC
- **Analysis 3:** 4D Modeling as a Comparison Tool
- **Acknowledgements**
- **Conclusion**
- **Questions/ Comments**

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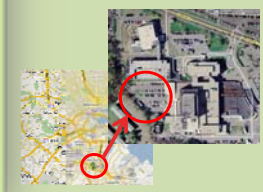
Baltimore Washington Medical Center Existing Site



Project Overview

- Located at 301 Hospital Drive, Glen Burnie, MD
- One of two new additions to the Baltimore Washington Medical Center site
- Existing Site: parking lot located adjacent to the existing hospital
- Two main bridges connect the Patient Tower to the existing hospital

Patient Tower Addition

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Project Overview

- **Size:**
  - 310,290 SF
  - 8 Story Patient Tower with Mechanical Penthouse
- **Facilities:**
  - Inpatient Care
  - Women's Care Center with obstetrics unit
- **Total Project Cost:**
  - $68.1 Million
- **Dates of Construction:**
  - July 2006-March 2009
- **Project Delivery Method:**
  - CM @ Risk

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Project Overview

Systems Summary

- **Building Envelope**
  - EIFS System with Ribbon Window Units
  - Brick Veneer System
  - Glass Curtain Wall
  - Composite Metal Panels
- **Structural System**
  - Spread Footings
  - Helical Piers to support existing building
  - Primarily Cast-in-Place Concrete
  - Small Section is Steel with Precast Planks
- **Architecture**
  - Façade designed to match Tate Cancer Center located in front of patient tower

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Client/ Owner

Construction Manager

Architect

Structural Engineer

Mechanical/ Plumbing Engineer

Project Overview

Project Team

- **Owner:** University of Maryland Medical System
- **Construction Manager:** Whiting-Turner Contracting Company
- **Architect:** Cannon Design
- **Structural Engineer:** Whitney, Bailey, Cox, and Magnani
- **Mechanical/ Plumbing Engineer:** Leach Wallace Associates, Inc.

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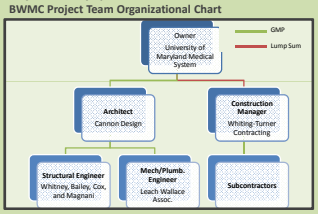
Project Delivery System: CM @ Risk with a GMP
BWMC Project Team Organizational Chart



Analysis 1
Precast Concrete Planks vs. Composite Slab

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Analysis 1: Precast Planks vs. Composite Slab

Problem

- Majority of Building is Cast-in-Place Concrete
- Patient Tower is built overtop of an existing mechanical room
  - This area uses steel and precast planks for the structure (Levels 3-9) instead of concrete
- Main Issue with Precast Planks in this area: Cost and Constructability

Goal

- Redesign this area of the structure using a composite slab system

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Analysis 1: Precast Planks vs. Composite Slab

Analysis Techniques

- Design wide flange beams for composite slab system using RAM Structures
- Design the connection between the steel and cast-in-place concrete beams
- Compare cost, schedule, and constructability for two systems

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Beam Design

Analysis 1: Precast Planks vs. Composite Slab

Composite Slab Design

- Composite slab designed using RAM Structures
- A 3" composite metal decking with a 3" normal-weight concrete slab was chosen for this area
- Steel beams are spaced 12' to meet the max metal decking span
- Calculated Loads for the Area: Dead Load of 84 psf and live load of 100 psf
- Based on the calculated loads and spacing of the beams, the beams designed in RAM Structures are 8x10 wide-flange beams

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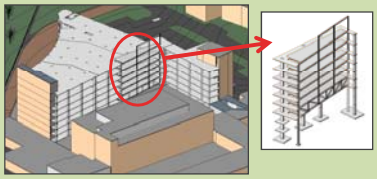
Composite Slab Design



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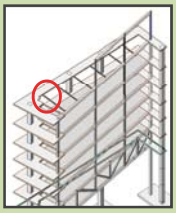
Connection Area

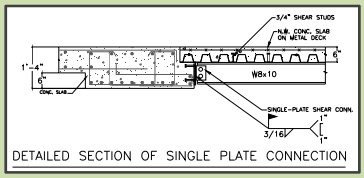


Analysis 1: Precast Planks vs. Composite Slab

Connection Design

- The connection design between the cast-in-place concrete beam and the 8x10 steel beams is a Single Plate Connection
- To fit the height of an 8x10 beam, a ¼" thick , 5 ½" long plate was chosen
- The connection uses (2) ¾" threaded A325 bolts and a 3/16" weld

Single Plate Connection Design



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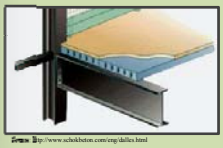
Analysis 1: Precast Planks vs. Composite Slab

Precast Planks Cost Estimate:

- 8" Hollow Core Planks
- 2" Concrete Topping w/ welded wire fabric



From: http://www.schokbeton.com/eng/dalles.html

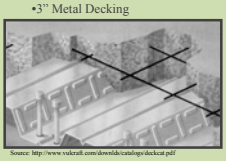
Cost Comparison

Cost Comparison of Structural Systems				
Structural System	Unit	Quantity	Unit Cost	Total Cost
Precast Hollow Core Planks				
8" Planks	plank	70	$1,840.00	$128,800
2" Concrete Topping w/ W.W.F	sf	7252	$5.00	$36,260
			Total Precast Planks Cost=	$165,060
Composite Slab				
W 8x10 Beams	lf	469	$17.65	$8,278
6" Concrete Slab w/ W.W.F	sf	7,252	$6.00	$43,512
3" Metal Decking	sf	7,252	$3.00	$21,756
			Total Composite Slab Cost=	$73,546
			Cost Difference=	**$91,500**

Save $91,500 with Composite Slab System

Composite Slab Cost Estimate:

- W 8x10 Beams
- 6" Concrete Slab w/ welded wire fabric
- 3" Metal Decking



Source: http://www.vulcraft.com/downlds/catalogs/deckcat.pdf

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Analysis 1: Precast Planks vs. Composite Slab

Schedule Comparison

Schedule Duration Comparison of Structural Systems			
Structural System	Duration/ Level (Days)	# of Levels	Total Duration
Precast Hollow Core Planks			
Erect 8" Precast Planks	1	7	7
Place 2" Concrete Topping w/ W.W.F	1	7	7
	Precast Planks Total Schedule Duration=		14
Composite Slab			
Erect W8x10 Beams and Metal Decking	1	7	7
Place 6" Concrete Slab w/ W.W.F	1	7	7
	Composite Slab Total Schedule Duration=		14
	Schedule Duration Difference=		**0**

- Same Schedule Durations
- 4D Model to illustrate schedule sequencing of two systems

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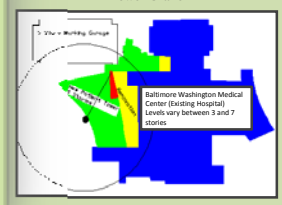
Analysis 1: Precast Planks vs. Composite Slab

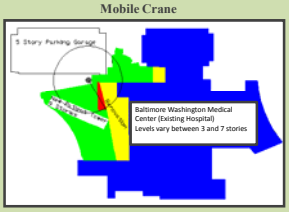
Constructability

- Precast Planks:
  - Precast Planks are erected with a tower crane
    - Precast planks erected on Saturdays
- Composite Slab:
  - Steel beams and metal decking can be erected with a mobile crane
    - Steel beams and decking can be erected on any day

Tower Crane



Mobile Crane



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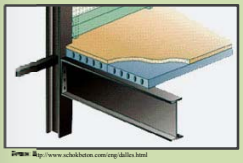
Analysis 1: Precast Planks vs. Composite Slab

Precast Planks

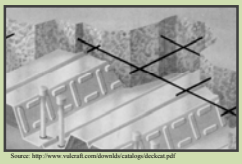


Source: http://www.schokbeton.com/eng/dalles.html

Conclusion

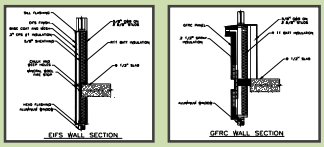
- **The composite slab system is a better alternative for this area of the structure:**
  - **Cost savings of $91,500**
  - **Same schedule duration**
  - **Easier to construct: does not require use of tower crane**

Composite Slab



Source: http://www.valcraft.com/downlds/catalogs/deckcat.pdf

Analysis 2
EIFS Panels vs. GFRC Panels



Analysis 2: EIFS Panels vs. GFRC Panels

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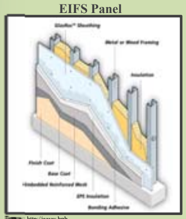
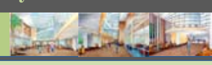
EIFS Panel



http://www.bpb-
us/english/high_performance_sheathing/downloads/EIFS.jpg



Problem

- •Problems with EIFS installation on site
- •Poor installation of EIFS can cause water problems and mold issues
- •Installation of EIFS is tedious and labor intensive

Goal

- •Redesign the façade system using the original façade system- Glass Fiber Reinforced Concrete (GFRC)

GFRC Panel

Source:http://www.wbdg.org/resources/env_seismicsafety.php?r=envelope

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Analysis 2: EIFS Panels vs. GFRC Panels

Analysis Techniques

- Determine the type and thickness of materials for both façade systems
- Calculate and compare the heat loss and heat gain for each system
- Compare the initial and life cycle costs
- Compare the schedule durations

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Analysis 2: EIFS Panels vs. GFRC Panels

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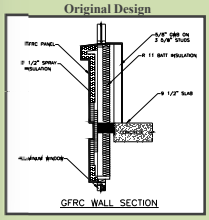
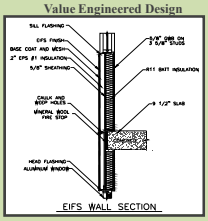
Original Design



Existing Conditions

- **Original Design:** GFRC Facade
  - GFRC Panel attached to 3 5/8" metal studs
  - 2 ½" Spray Polyurethane Foam Insulation
- **Value Engineered Design:** EIFS Facade
  - EIFS Panel with 2" Expanded Polystyrene Foam Insulation
  - 5/8" DensGlass Sheating attached to 3 5/8" metal studs

Value Engineered Design



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EIFS System U-value

R-Values and U-Values for Exterior Insulation Finishing System (EIFS)

	Thickness (in.)	R-Value / Thickness (in)	R-Value (hr ft² °F/ BTU)
[illegible]	-	-	-
[illegible]	-	-	-
[illegible]	-	-	-
[illegible]	2	4.00	8
[illegible]	-	-	-
[illegible]	-	-	-
[illegible] Sheeting	0.625	-	0.67
[illegible]	-	-	-
[illegible]	3.5	-	11
[illegible]	0.625	-	0.67
	Total R-Value	hr ft2 °F/ BTU	20.34
	U-Value (1/R)	BTU/ hr ft2 °F	0.0492

Analysis 2: EIFS Panels vs. GFRC Panels

Thermal Quality

Summer Cooling Loads for Baltimore, MD

Outside Dry Bulb Design Temperature (To)	91°F
Inside Dry Bulb Design Temperature (Ti)	75°F
Change in Temperature (ΔT)	16°F

Winter Heating Loads for Baltimore, MD

Outside Dry Bulb Design Temperature (To)	13°F
Inside Dry Bulb Design Temperature (Ti)	70°F
Change in Temperature (ΔT)	57°F

Heat Transfer Equation: $qx = \Delta T * A * U$

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GFRC System U-value

R-Values and U-Values for Glass Fiber Reinforced Concrete (GFRC)

Components	Thickness (in)	R-Value / Thickness (in)	R-Value (hr ft² °F/ BTU)
GFRC Skin	0.50	0.14	0.07
2 1/2" Spray Insulation	2.5	6	15
3 5/8" Metal Studs	-	-	-
R 11 Batt Insulation	3.5	-	11
5/8" GWB	0.625	-	0.67
	Total R-Value	hr ft2 °F/ BTU	26.74
	U-Value (1/R)	BTU/ hr ft2 °F	0.0374

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Analysis 2: EIFS Panels vs. GFRC Panels

Thermal Quality

Summer Heat Gain

Façade System	Area (SF)	U-Value (BTU/hr ft2 °F)	ΔT (°F)	Heat Gain (BTU/hr)	Heat Gain (Tons=12,000 BTU/hr)
EIFS	45690	0.0492	16	35967	3.0
GFRC	45690	0.0374	16	27341	2.3
				Difference (Tons) :	0.7

Winter Heat Loss

Façade System	Area (SF)	U-Value (BTU/hr ft2 °F)	ΔT (°F)	Heat Loss (BTU/hr)	Heat Loss (Tons=12,000 BTU/hr
EIFS	45690	0.0492	57	128133	10.7
GFRC	45690	0.0374	57	97402	8.1
				Difference (Tons) :	2.6

- Negligible Difference in Summer Heat Gain
- Significant Difference in Winter Heat Loss
- Overall, the GFRC System is the better thermal insulator

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Analysis 2: EIFS Panels vs. GFRC Panels

Initial Cost Comparison

Initial Cost Comparison of Facade Systems				
Facade System	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
EIFS Facade				
EIFS Panels	sf	45,690	$12.50	$571,125
Non-Structural Metal Studs	sf	45,690	$1.10	$50,259
Exterior Sheating	sf	45,690	$1.07	$48,888
			Total EIFS Cost=	$670,272
GFRC Facade				
GFRC Panels	sf	45,690	$45.00	$2,056,050
2 1/2" Spray Polyurethane Foam Insulation	sf	45,690	$3.78	$172,708
			Total GFRC Cost=	$2,228,758
			Cost Difference=	**$1,558,500**

GFRC is $1.55 million more than the EIFS in terms of initial cost

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EIFS Maintenance Costs

Life Cycle Cost of EIFS				
	Quantity	Unit	Unit Cost	Total Cost
[illegible]em	45690	sf	$4.67	$670,272
[illegible]intenance				
Cleaning	45690	sf	$0.30	$13,707
[illegible]coat Panels	45690	sf	$2.00	$91,380
[illegible]Joint Sealant	12000	lf	$2.50	$30,000

Analysis 2: EIFS Panels vs. GFRC Panels

Life Cycle Cost Comparison

Life Cycle Cost Comparison of Facade Systems							
Facade System	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Total Cost
EIFS Facade							
Initial Cost	$670,270						$670,270
Description of Maintenance							
Cleaning		$15,890	$18,421	$21,355	$24,756	$28,699	$169,121
Re-coat Panels					$165,042		$165,042
Replace Joint Sealant			$16,127		$21,673		$37,800
						Total EIFS Cost=	$1,072,233
GFRC Facade							
Initial Cost	$2,228,758						$2,228,758
Description of Maintenance							
Replace Joint Sealant					$21,673		$21,673
Cleaning						$68,879	$68,879
						Total GFRC Cost=	$2,319,311
						Cost Difference=	$1,337,000

GFRC is still more in terms of a 25 year life cycle cost costs

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GFRC Maintenance Costs

Life Cycle Cost of GFRC				
	Quantity	Unit	Unit Cost	Total Cost
Initial Cost of System	45690	sf	48.78	$2,228,758
Description of Maintenance				
Cleaning	45690	sf	$0.72	$32,897
Replace Joint Sealant	12000	lf	$2.50	$30,000

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EIFS System

Multiple faces erected at one time using Scaffolding

Analysis 2: EIFS Panels vs. GFRC Panels

Schedule Comparison

Schedule Duration Comparison of Facade Systems	
Facade System	**Total Duration (Days)**
EIFS System	
Metal Studs	50
EIFS Panels + Windows	72
EIFS Total Schedule Duration=	122
GFRC System	
GFRC Panels + Windows	29
GFRC Total Schedule Duration=	29
Schedule Duration Difference=	**93**

- **Save 93 days using the GFRC System**
- **4D Model to illustrate schedule sequencing of two systems**

GFRC System

One face erected at a time using Tower Crane

Analysis 2: EIFS Panels vs. GFRC Panels

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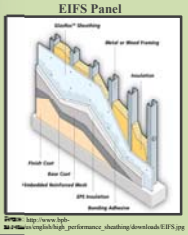
EIFS Panel



http://www.hpb-[illegible]/english/high_performance_sheathing/downloads/EIFS.jpg

Conclusion

- GFRC Panels
  - With the 2 ½" spray foam insulation, the GFRC has better thermal quality
  - Schedule reduced by 93 days
  - The panels are prefabricated; therefore, construction process is much faster and easier.
  - Has a higher initial and life cycle cost
- Overall, the GFRC Panels is the best system in terms of quality
- Due to budget constraints, the EIFS is still the best for this project

GFRC Panel

Source http://www.wbdg.org/resources/env_aesthetically.php?v=envelope

Analysis 3
4D Modeling as a Comparison Tool

Analysis 3: 4D Modeling as Comparison Tool

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Goal of Research

- Develop a process to compare two systems using single 4D Model
- Use process and 4D tool to compare first two analysis areas

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Example of 3D Model Pieces

3D View (ex. 2Bs)

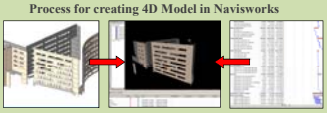
Visibility Settings Box

Analysis 3: 4D Modeling as Comparison Tool

Analysis Techniques

- 3D Model created in Revit Architecture
- 3D Model was broken up for the structural analysis and the façade analysis
- The 3D Model and CPM schedule for each analysis area were linked in the Navisworks Timeliner Program
- The construction sequencing for the two alternatives within an analysis area were simulated and compared using the 4D Models

Process for creating 4D Model in Navisworks



Model Component (ex. GFRC Walls)

Navisworks Jetstream v. 5 TimeLiner

CPM Schedule

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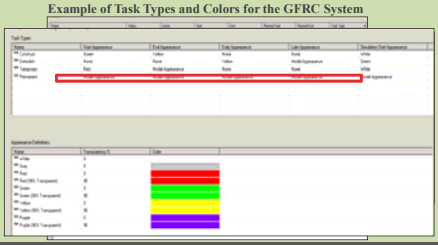
Analysis 3: 4D Modeling as Comparison Tool

4D Modeling Process

- **Original Idea:** Simulate both systems using a single 4D Model
- Based on idea, one schedule that included both systems within the analysis was created
- A different task type was assigned to each system within the analysis area
- The task type for each system was then assigned two colors- one for the start appearance and one for the end appearance

Example of Task Types and Colors for the GFRC System



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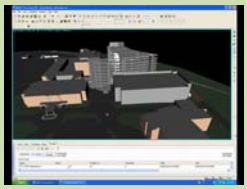
Analysis 3: 4D Modeling as Comparison Tool

Structural 4D Model



Color Legend

Green- Composite Slab is being constructed

Yellow- Composite Slab is completed

Red- Precast Planks are being constructed

Model Appearance- Precast Planks are completed

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Facade 4D Model- Option #1

Color Legend

Green- EIFS is being constructed

Yellow- GFRC is completed

Red- GFRC is being constructed

Model Appearance- EIFS is completed

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Analysis 3: 4D Modeling as Comparison Tool

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Problems with Facade 4D Model

- Many times the EIFS and GFRC would be constructed on the same face at the same time
- Only one color would be displayed when the EIFS and GFRC were going up on the same face
- With only one color appearing, it was difficult to tell when both systems were going up at the same time

Example: Both systems being constructed but only one color displayed

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Analysis 3: 4D Modeling as Comparison Tool

Facade 4D Model Solution

- Two 4D Models are created to simulate each system
- Both systems are simulated side by side at the same time
- The same colors are used to display the start and end appearances for EIFS and GFRC

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Facade 4D Model- Option #2

EIFS Façade System | GFRC Façade System

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Analysis 3: 4D Modeling as Comparison Tool

Conclusion

Using a single 4D Model to compare two systems is not effective in all situations

- Single model works well for simulations when one system is constructed before the second system begins in that area
  - Ex. Structural 4D Model
- Single model does not work well for simulations when both systems are being constructed in the same area at the same time
  - Ex. Façade 4D Model
  - For this situation, two models side by side are more effective

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Acknowledgements

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Family and Friends

Precast Concrete Planks vs. Composite Slab

Use composite slab system in place of precast hollow core planks

- Cost savings of $91,500
- Easier to construct

EIFS vs. GFRC

GFRC Panels:

- Better thermal quality
- Schedule reduced by 93 days
- Easier to construct

EIFS Panels:

- Save $1.33 million with this system

4D Modeling as a Comparison Tool

Using a single 4D Model to compare two systems is not effective in all situations

- Single model works well for Structural 4D Model
- Single model does not work well for Façade 4D Model

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Analysis 1: Precast Planks vs. Composite Slab

Formwork and Shoring

- For the third floor, any formwork and shoring required cannot be supported from below (where existing mechanical room is located)
- For the third floor, the formwork and shoring must be cantilevered from the existing cast-in-place system
- For levels four through nine, the floors below can support the formwork and shoring

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Cantilevered Formwork and Shoring

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Analysis 1: Precast Planks vs. Composite Slab

Beam Design

Eq. 1: Dead Load Equation

DL= 5psf (MEP Equip.) + 2psf (Ceiling Load) + 2psf (Misc.) + 75psf (Comp. Slab)* = 84

*Composite Slab= 6" Concrete Slab (Normal Weight- 145pcf) + Metal Decking (2.5 psf)

DL= .5' x 145pcf + 2.5psf= 75psf

Eq. 2: Live Load Equation

LL= 80psf + 20psf (partition walls) = 100psf

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Analysis 1: Precast Planks vs. Composite Slab

Connection Design

Eq. 3: Factored Loads

FL=1.2DL + 1.6LL

FL=1.2 (84psf) + 1.6 (100psf) = 261psf

Eq. 4: Reaction Force

R= (wl)/2= (3132psf x 17')/2= 26622lbs ~ 26.6kips

w= FL x trib. width of beam

w= 261psf x 12' = 3132plf

l= length of longest beam

l= 17'

Eq. 5: LFRD

LFRD= ϕ R= (.75) (26.6kips) = 19.95 ~ 20.0kips

Φ= .75

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Analysis 2: EIFS Panels vs. GFRC Panels

Structural Impact

- GFRC Panels are considered to be light-weight precast panel
  - The difference in weight between the EIFS and GFRC is minimal
- The concrete structure was designed based on the structural load of the GFRC Panel design
- The redesign of the façade using GFRC Panels has no structural impact on the concrete structure

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Analysis 2: EIFS Panels vs. GFRC Panels

EIFS Durations

EIFS Schedule Durations	
Area	Duration (Days
Metal Studs (All Faces)	50
EIFS	65
Total EIFS plus Windows	72
Extra Time for Windows L1-L8 After EIFS Finished	7
Total Duration (Days)=	122

Schedule Durations

- The EIFS Panels and metal studs take 122 Days
- The EIFS Panels alone take 65 Days
- The 4D Models only simulate the EIFS and GFRC Panels

GFRC Durations

GFRC Schedule Durations	
Area	Duration (Days
GFRC	20
Total GFRC plus Windows	29
Extra Time for Windows After GFRC Finished	9
Total Duration (Days)=	29