Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner





Project Background Project Background Research Focus Alternative Dobrey Method Chilled Beams Coat & Schedule Impac Cancrete Overpour Due to Sted Deflection Conchronon Acknowledgements Questions

#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option

astruction Management Op Advisor: Dr. John I. Messner

#### Introduction

Project Background

Research Focus

Alternative Delivery Method (MAE)

- Chilled Beam Cost & Schedule Impact (Mech. Breadth)
- Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth)
- Acknowledgem





#### Project Background

Johns Hopkins Hospital Ranked #1 Hospital since 1992 by U.S. News & World Report Annual Operating Budget = \$4.1 Billion (2007)
 \*82,523 Admissions, 72,797 Surgeries, 205,034 ER Visits
 4.2 Million Square Feet of Building Space



Involucion Project Background Research Focus Alienative Delivery Method Chilled Beams Cost & Schedule Impa Concrete Over-pour Due to Steel Deflection Acknowledg

Alternative Delivery Method Chilled Beams Cost & Schedule Impact

Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgen

#### Johns Hopkins Hospital

New Clinical Building Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option

April 14, 2009

Johns Hopkins Hospital

New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

#### Project Background

Banked #1 Hospital since 1992 by U.S. News & World Report
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•1.2 Million Square Feet of Building Space

New Clinical Building • Two Towers - Adult and Children's with Connector • 1.6 Million SF • 8573 Million GMP Surrounded by operating hospitals throughout construction



# Research Focusardini Research Focus Alternative Delivery Method Colliele Beams Cost & Schedhile Impac Concrete Over-pour Due to Steel Deflection Conclusions Acknowledge

#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option April 14, 2009

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option

Advisor: Dr. John I. Messner

#### Project Background

Johns Hopkins Hospital • Ranked #1 Hospital since 1992 by U.S. News & World Report Annual Operating Budget = \$4.1 Billion (2007)
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 4.2 Million Square Feet of Building Space

New Clinical Building • Two Towers - Adult and Children's with Connector • 1.6 Million SF • \$573 Million GMP Oct. 2006 - Dec. 2010
 Design-Bid-Build, Fast-track schedule



Alternative Delivery Method Chilled Beams Cost & Schedule Impact Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgem

#### Project Background

Banked #1 Hospital since 1992 by U.S. News & World Report
Annual Operating Bodget = \$4.1 Billion (2007)
•82,523 Admissions, 72,797 Surgeries, 205,034 ER Visits
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New Clinical Building • Two Towers - Adult and Children's with Connector • 1.6 Million SF • 8573 Million GMP

Surrounded by operating hospitals throughout construction



# Introduction Project Background Research Core Alternative Delivery Method Colled Beams Con & Schedule Impact Controls Con & Schedule Impact Dediction Conchainon Achaowledgements Questions

#### Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner

#### **Research Focus**

"Explore alternatives and procedures that could have been implemented on the NCB to avoid or reduce the number of changes and constructability challenges."

		WEIGHT MA	TRIX		
Description	Research	Value	Constructability	Schedule	Total
		Engineering	Review	Reduction	
Alter: Delivery Method	20%	5%		10%	35%
Chilled Beams	10%	10%	5%	15%	40%
Conc. Over-pour on Decks			25%		25%
Total	30%	15%	30%	25%	100%

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Project Background Research Focus

Chilled Bears Cost& Schedule Impact Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements Questions

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#### Alternative Delivery Method (MAE)

Alternative Delivery M Problem Statement 1 Indianal Design-bid-build with Fast-mack 0 (C CD) 2 (D CD)

#### Alternative Delivery Method (MAE)

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Coal
Demonstrate that an alternative delivery method could have more effectively
managed the changes while meeting the Owner's goals.

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Chilled Beams Cost & Schedule Inu Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements Questions

Introduction Project Backgros Research Focus

Conclusions Acknowledge

Chilled Beams Cost & Schedule Impact Concrete Over-pour Due to Steel Deflection

Alternative Delivery Method (MAE)

Analysis Construction Industry Institute's Project Delivery and Contract Strategies (PDCS) Tool 12 Possible Delivery Method Outcomes

#### Possible Project Delivery Outcomes

<u>resume Project Delivery Outcomes</u>
 1. Traditional Design-Jahrhuld
 2. Traditional with Early Procurement
 3. Traditional with Construction Manager
 4. Traditional with Construction Manager
 5. Traditional with Construction Manager
 6. CM at Ris
 7. Design-Build
 8. Multiple Design-Build
 9. Parallel Primes
 10. Traditional with Staged Development
 11. Turnkey
 12. Fast Track

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Introduction Project Backgrou Research Focus

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Chilled Beams Cost & Schedule Impact Concrete Over-pour Due to Steel Deflection

Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements

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#### Alternative Delivery Method (MAE)

Analysis • Cor 1993 Construction Industry Institute's Project Delivery and Contract Strategies (PDCS) Tool 12 Possible Delivery Method Outcomes \*20 Selection Factors

- Section Factors
  1. Completion within Budget
  2. Minimal Cost
  3. Cash Poix to Constrained
  4. Owner Requires Early Cost Figures for Planning
  5. Owner Assumes Minimal Fanancial Rak
  6. Completion within Schedule
  7. Early Completion
  8. Early Poerurement for Long Lead Hens
  9. Above Arcrage Number of Changes are Anticipated
  10. Below Arcrage Number of Changes are Anticipated
  11. Confidentially of Business Fangueering Details
  12. Local Conditions are Flavonable
  13. Owner Desires High Depare of Control
  14. Comfort Schedule
  15. Owner Desires High Depare of Control
  16. Owner Desires High Depare of Control
  16. Owner Desires High Depare of Control
  16. Owner Desires Wei of Own Resources
  17. Pogert Weil Defined an Hol
  19. Owner Prefers Minimal K woll Bed
  20. Project is Complex, Innovative or Non-Standard

#### Alternative Delivery Method (MAE)

 Analysis
 • Construction Industry Institute's Project Delivery and Contract Strategies (PDCS) Tool

 • 12 Possible Delivery Method Outcomes
 • 20 Selection Fractors

 • 20 Selection Fractors
 • Surveyed Owner, A.F., and CM Principles

#### Selection Factors

- Completion within Budget
   Minimal Cost
   Minimal Cost
   Cash Flow is Constrained
   Owner Requires Early Cost Figures for Planning
   Owner Assumes Minimal Financial Risk
- Completion within Schedule
   A completion

- Above Average Number of Changes are Anticipated
   Below Average Number of Changes are Anticipated
   Confidentiality of Business/Engineering Details
   Local Conditions are Favorable
   Owner Desires High Desree of Control

- 13. Owner Desires High Degree of Control
   14. Owner Desires Low Degree of Control
   15. Owner Desires Use of Own Resources
   16. Owner Desires Minimal Use of Own Resources
   17. Project Well Defined at Bid
   18. Decen Vell Ub/femora Pala
- Project Not Well Defined at Bid
   Owner Prefers Minimal Number of Parties Responsible
   Project is Complex, Innovative or Non-Standard

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Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

#### Introduction Project Background Research Focus Vaname Thebrer Machae Chilled Beams Cost & Schechtel Impact Contrets Overspoor Due to Steel Deflection Conchesions Acknowledgements Questions

Project Backgrou Research Focus

Chilled Beams Cost & Schedule Impact Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements Questions

### Alternative Delivery Method (MAE)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner Aniil 11 9000 Analysis • Construction Industry Institute's Project Delivery and Contract Strategies (PDC8) Tool • 12 Possible Delivery Method Ourcomes • 20 Selection Factors • Surveyed Omer, A.V., and CM Principles • PDCS Results • Tora 3 Delivery Methods • Integrated Project Delivery • Integrated Project Delivery • Design-Build • Traditional with Early Procurement and Project Manager Owner's PDCS Results Turkey - 81.13 Design-Build - 77.64

<u>CM's PDCS Results</u> CM@Risk - 68.05 Turkey - 64.91 A/F's PDCS Results

<u>A/E's PDCS Results</u> Traditional Design-Bid-Build - 76.25 Traditional with CM - 74.52

#### Alternative Delivery Method (MAE)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 3th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009 Integrated Project Delivery • Not Instaled in PDCS • Critical Industry Issue • Statter Health System - Camino Medical Center • &80M • Saved &90M and 6 Months Over Traditional Methods

# Introduction Project Backgrou Research Focus Chilled Beams Cost & Schedule Impact Concrete Over-pour Due to Steel Deflection Conclusions Acknowledge

Chilled Beams Cost & Schedule Ing Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements Questions

#### Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option

April 14, 2009

Alternative Delivery Method (MAE) Integrated Project Delivery • Not Included in PDCS • Critical Industry Issue • Stutter Health System - Camino Medical Center • \$98M • Sweed \$9M and 6 Months Over Traditional Methods • Principles of IPD

#### IPD Principals

- International Respect & Trust
   Manual Benefit and Reward
   Manual Benefit and Reward
   Gallaborative Innovation and Decision
   Methods and the second second

#### Alternative Delivery Method (MAE)

#### Integrated Project Delivery

Advantages • BIM Reduce Project Disputes • Mendre Specialty Contractors Early • Well Defined Soupe for All Team Players • Open Communication, Pricing, Schedule, and Quality - Better CO Management

# <u>Disadvantages</u> • Not a Familiar Delivery Method in Region • More Risk for Bidders • Not a Proven Delivery Method – Too Risky for this Project





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#### Alternative Delivery Method (MAE)

Design-Build

Advantages • Team Approach • Constructability Issues Addressed Early in Design • Better Control of Budget in Design and Construction Phase

<u>Disadvantages</u> •Would Not Accelerate Project • No Checks and Balance • Risk of Sacrificing Design Quality to Protect Design-Builder's Profits



# Research Focus

Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

#### Alternative Delivery Method (MAE)

Design-Build MEP • Changes have Increased MEP Trades Contracts by 17%. • Severely Imparted Coordination and Perchabrication • Las-minute Drawings • Eliminated All of the Float • DB MEP would have Cost 5% More Initially

Advantages

• Involved Early in Design
• V/E
• Schechole Input
• Early Coordination, Procurement, and Prefabrication

Disadvantages • Initial Cost



#### Introduction Projet Background Research Force Research Force Market Market Childfel Beams Core & Schechtel Impact Controls Overspoor Due to Steel Deflection Conchroison Acknowledgements Questions

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Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner

#### Alternative Delivery Method (MAE)

Traditional w/Early Procurement and PM • Same Delivery Method Except for PM • KLMK Group <u>Arbantages</u> • PM has Extensive Experience

Advantages • PM has Extensive Experience • PM Familiar with Team Players • Checks and Balance • Assist Owner with Managing CO's • Assist with Close-ont and Occupancy • Assist with Master Planning <u>Disadvantages</u>

Disadvantages

Initial Cost of 1% of Total Project Cost
May Create Hostile Environment



### Johns Hopkins Hospital

New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009 Conclusion • PDCS Did Not Identify Best Delivery Method • Handsight is 20/20 • Best Alternative is a Mix of the Top 3 • PM • DD MEP • IPD Principles • Manage CO's More Efficiently

Alternative Delivery Method (MAE)

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#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Research Focus Alternative Delivery Method

Acknowled

Dan Weiger Architectural Engineering, 5th Year Construction Management Option April 14, 2009

Problem Statement • Top 2 Goals for the Owner, A/E, and CM are Not Being Met • 1° Package of Changes (CDI 1-38) > 7 Months Delay > Cost to Accelerate to 3 Months Delay = 82M > Mechanical Systems is Imparted the Most

Coal
Demonstrate that Chilled Beam HVAC Systems in Non-Invasive Spaces have the
Posentialto Lower Coss Unitial and Life-Cycle) and Accelerate the Schedule.

# Johns Hopkins Hospital New Clinical Building Baltimore, MD Concrete Over-pour Due to Steel Deflection Conclusions Acknowledgements Questions

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#### Chilled Beams Cost & Schedule Impact (Mechanical)

Current Design • VAV System with Reheat Coils on Each VAV Box Mech, Package Accounts for 29,1% of Construction Cost • HVAC System Tools 13,9% or 879,444,970 • Critical Path Largely Involves HVAC Overhead • Central Unity Plant Provides Chilled Water and Steam

Method • Research Chilled Beams • Contact Industry Experts • Size Chilled Beams • Evaluate Initial Cost • Evaluate Life-Cycle Cost • Evaluate Schedule Impact

#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009 Chilled Beam System • Emerging Technology from Europe • Few Projects in the USA. > Constitution Center in D.C. > Yale Hospital Expansion in New Haven, CT

#### Introduction Project Background Research Form Alternative Delivery Method Lennite Delivery Method Lennite Deveryour Due to Steel Deliverion Canchations Acknowledgments Questions

Concrete O Deflection Conclusion Acknowleds

#### Chilled Beams Cost & Schedule Impact (Mechanical)

 Chilled Beam System

 • Emerging Technology from Europe

 • Fere Projects in the U.S.A.

 > Constitution Center in D.C.

 > Yake Hospital Expansion in New Haven, CT

 • Scare Eurogy

 • Reduce Sizes of Ductwork, AHUs, Fans, etc.



Johns Hopkins Hospital New Clinical Building Balimore, MD Dan Weiger

Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009

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Johns Hopkins Hospital

New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option

Advisor: Dr. John I. Messner

 Chilled Beam System

 \*Inserging Technology from Europe

 \*Fore Projects in the U.S.A.

 >Constitution Center in D.C.

 > Yale Hoopin Expansion in New Haven, CT

 \*Save Energy

 Reduce Xios of Durtwork, AUUs, Fans, etc.

 \*Two Childed Beams

 > Pasite

 > Autors



# Conclusions Acknowledgements Questions

Conclusions Acknowledg

#### Chilled Beams Cost & Schedule Impact (Mechanical)

Childed Beam System • Lenarging Technology from Europe • Ten Projects in the U.S.A. > Constitution Center in D.C. > Yale Hospital Expansion in New Haven, CT > Nave Eurogy • Reduce Szics of Dactwork, AHUS, Fans, etc. • Two Types of Childed Beams > Passive > Passive > Aurits • Many Advantages > Low Europy Constitution > Engreeo Response > Engreeo Respo



13

Johns Hopkins Hospital New Clinical Building Baltimore, MD

> Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009

 Sizing the Chilled Beam System

 • Current VAT System will Remain in Invasive Spaces (ORs, Trauma, Exam Rooms, etc.)

 • Elamine Typical Areas of Nour-Invasive Spaces

 • Offices

 • Differs

 • Brainer Rooms

 • Brainer Rooms

 • Stargohart Results to Remaining Areas

 Sizing Calculations

 • Soler Primary Auto Meet OA or Latent Requirements

 • Chilled Beam will be Sized to Handle Red of Sensible Load

 • Samuer Stapp CM on Daways Represent Design Loads

 • Sizing is based on Cooling

 • Heating Coll Will be Required on Perimeter Spaces

#### Introducion Projeti Background Research Fortu Alternative Delivery Method Charles from et al. 1 & Undel Charles Controls Overspoor Due to Steel Deflection Conchoison Conchoison

Conclusions Acknowledge

Chilled Beams Cost & Schedule Impact (Mechanical)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner Sizing Example • Typ. Office Space on Level 6 • VAV Box S0D-1 • Total Supply - 300 CFM • 6 Person Occupancy • 1 Room is Served by VAV • Room Temp - 70°F • Supply Temp - 55°F



1. Total Sensible Design Load ~ 1.08 x Total Supply CFM x (Room Temp – Supply Temp) = 1.08 x 200 CFM x (70°F - 55°F) = 4.860 BTU/hr

#### Introduction Project Background Research Forcus Alternative Delivery Method Concrete Over-pour Date to Steel Deflection Conclusions Conclusions

Project Backs

Research Focus

Conclusions Acknowledgen Johns Hopkins Hospital New Clinical Building Baltimore, MD

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#### Chilled Beams Cost & Schedule Impact (Mechanical)

1. Total Sensible Design Load ~ 1.08 x Total Supply CFM x (Room Temp – Supply Temp) = 1.08 x 300 CFM x (70 ° F - 55 ° F) = 4,860 BTU/hr

 Ventilation air required per ASHRAE.62.1 - 2007 is 25 CFM/person for patient rooms. Office spaces are not shown. To be on the conservative side, 25 CFM/person will be used for both the office and patient rooms.



Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 3th Year Construction Management Option Advisor: Dr. John I. Messner Arril 14, 2009

#### Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option April 14, 2009

Chilled Beams Cost & Schedule Impact (Mechanical) 1. Total Sensible Design Load = 1.08 x Total Supply CFM x (Room Temp - Supply Temp) = 1.08 x 200 CFM x (70  $^\circ$  F - 5.5 F) = 4.860 BTU/hr

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Johns Hopkins Hospital New Clinical Building Baltimore, MD

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- 3. Ventilation Air Required = 25 CFM/person x 6 persons = 150 CFM
- 4. Assume that ventilation air governs primary air supply right now and then check to see if it is greater than the latent load air requirement later.



Project Backg

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Conclusions Acknowledgen

#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Question

Project Backs Research Focus

Conclusions Acknowledger

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1. Total Sensible Design Load = 1.08 x Total Supply CFM x (Room Temp - Supply Temp) = 1.08 x 200 CFM x (70  $^\circ$  F - 5.5 F) = 4.860 BTU/hr

- Ventilation air required per ASHRAE 62.1 2007 is 25 CFM/person for patient rooms. Office spaces are not shown. To be on the conservative side, 25 CFM/person will be used for both the office and patient rooms.
- Assume that ventilation air governs primary air supply right now and then check to see if it is greater than the latent load air requirement later.

5. Sensible Cooling Capacity of Primary Air = 1.08 x Vent. Air CFM x (Room Temp - Supply Temp) = 1.08 x 150 CFM x (70° F - 55° F) = 2,430 BTU/hr



#### Chilled Beams Cost & Schedule Impact (Mechanical)

6. Sensible Cooling by Chilled Beam – Total Sensible Load – Sensible Capacity of Primary Air – 4,860 BTU/hr – 2,430 BTU/hr – 2,430 BTU/hr



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Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner Arril 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

6. Sensible Cooling by Chilled Beam – Total Sensible Load – Sensible Capacity of Primary Air – 4,860 BTU/hr – 2,430 BTU/hr – 2,430 BTU/hr

7. Latent load in the room can be approximated by the general rule of thumb that each person gives off 200 BTU/hr of latent load.



#### Chilled Beams Cost & Schedule Impact (Mechanical)

6. Scnsible Cooling by Chilled Beam – Total Sensible Load – Sensible Capacity of Primary Air – 4,860 BTU/hr – 2,430 BTU/hr – 2,430 BTU/hr

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Latent Load = 200 BTU/hr/person x 6 person = 1,200 BTU/hr



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r Due to Steel

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Dan Weiger Architectural Engineering, 5th Year Construction Management Option

Advisor: Dr. John I. Messner

6. Sensible Cooling by Chilled Beam - Total Sensible Load - Sensible Capacity of Primary Air - 4,860 BTU/hr - 2,130 BTU/hr - 2,130 BTU/hr

- 7. Latent load in the room can be approximated by the general rule of thumb that each person gives off 200 BTU/hr of latent load.
- 9. Latent Cooling Capacity of Primary Air = 4,840 x Vent. Air CFM x (W<sub>Reom</sub> = W<sub>Primary</sub>) = 4,840 x 150 CFM (0.009 0.007) = 1,452 BTU/hr



#### Chilled Beams Cost & Schedule Impact (Mechanical)

- 6. Sensible Cooling by Chilled Beam Total Sensible Load Sensible Capacity of Primary Air - 4.860 BTU/hr - 2.430 BTU/hr - 2.430 BTU/hr
- Latent load in the room can be approximated by the general rule of thumb that each person gives off 200 BTU/hr of latent load.
- . Latent Load = 200 BTU/hr/person x 6 person = 1,200 BTU/hr
- 9. Latent Cooling Capacity of Primary Air = 4.840 x Vent. Air CFM x (W $_{\rm Room}$  = W $_{\rm Primary})$  = 4.840 x 1.50 CPM (0.009 = 0.007) = 1,452 BTU/hr
- 10. The latent cooling capacity of primary air is greater than the latent load. Therefore, the ventilation air is adequate in supporting the latent load for the zone.



11. On average, a chilled beam can produce 1,000 BTU/hr/ft of sensible cooling capacity

#### Introduction Project Background Research Form Alternative Delivery Method United Delivery Method United Deliveron To Lee to Steel Deliveron Deflection Conchristions Acknowledgements Questions

Concrete Ow Deflection Conclusions Acknowledge Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 3th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009 12. Chilled Beam Size = 2,430 BTU/hr + 1,000 BTU/hr/ft = 2.43 ft Chilled Beam = 3 ft Chilled Beam



#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009 On average, a chilled beam can produce 1,000 BTU/hr/ft of sensible cooling capacity.
 Chilled Beam Size = 2,430 BTU/hr ÷ 1,000 BTU/hr/ft = 2.43 ft Chilled Beam = 3 ft Chilled Beam

13. Primary Air Reduction = 1 - (Primary Air CFM + Total Current Supply CFM) = 1 - (150 CFM + 300 CFM) = 50%



#### Introduction Project Background Research Form Alternative Delivey Method Concrete Overpour Date to Steel Deflection Conclusions Acknowledgements Questions

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nstruction Management Option Advisor: Dr. John I. Messner April 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

 Typ. Office Space

 • Prinary Air Roduction = 79%

 • Varcage Childe Beam Size per Room = 5 ft

 • Total Cost of CNM for Typical Area = 81,578 = 80,61/NF

 • Total Cost of Childe Beams for Typical Area = 81,02780 = \$1,16 SF

 • Prinary Air Read Beams over VAV Boxes = (325)

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# Johns Hopkins Hospital New Clinical Building Baltimore, MD

Research Focus Alternative Deliv

Conclusions Acknowledg

Conclusions Acknowledgements Questions

Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option Advisor: Dr. John I. Messner

 Typ. Office Snoce

 • Primary Air Reduction = 7096

 • Average Childed Beam Size per Room = 5 fi

 • Toda Cost of AVA's for Typical Area = \$15,078 = \$0,61/8F

 • Toda Cost of AVA's for Typical Area = \$15,078 = \$0,61/8F

 • Primeru Increase of Childel Beams for Typical Area = \$10,2700 = \$4,16/8F

 • Primeru Increase of Childel Beams over AVA Doxes = \$00200

 • Margae Childel Beams Size = \$2000 = \$6 fi

 • Average Childel Beams Size = \$60,86/8F

 • Total Cost of VAV's for Typical Area = \$6,85/1 = \$0,48/8F

 • Total Cost of Uhildel Beams Size = \$19,280 = \$3,26/85F

 • Total Cost of Uhildel Beams Size = \$19,280 = \$3,26/85F

 • Percent Increase of Childel Beams Size = \$19,280 = \$3,26/85F

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Chilled Bea	ms Cost & S	chedule Im	pact (Mechar	nical)
Cost Impact				

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option

<u>Cost Impact</u> • Total HVAC Cost • Break-down Material and Labor

	Total Proje	et HVAC Cost		
Description	Material	Labor	Total	% Total
Variable Frequency Drives	\$1,019,375	\$168,125	\$1,187,500	15
Hydronic Pump Package	\$159,283	\$85,702	\$244,985	0.3
Condensate Pump Sets	\$31,035	\$10,813	\$41,848	0.1
Steam Specialties	\$537,011	\$388,896	\$925,907	1.2
VAV Boxes & Terminals	\$760,743	\$267,290	\$1,028,033	1.3
Fans & Accessories	\$503,782	\$95,602	\$599,384	0.8
Clean Steam Generators	\$134,086	\$29,446	\$163,520	0.2
Duct Humidifiers	\$41,002	\$8,316	\$49,400	0.1
Castom AHUs	\$5,772,000	\$1,628,000	\$7,400,000	9.3
Ductwork	\$15,368,723	\$23,053,085	\$38,421,808	48.4
Controls	\$3,591,315	\$1,933,785	\$5,525,100	7.0
Mechanical Insulation	\$1,320,602	\$1,980,904	\$3,301,506	4.2
Test & Balance		\$725,000	\$725,000	0.9
Chilled Water Piping	\$3,366,041	\$1,891,780	\$5,257,821	6.6
Heating Hot Water Piping	\$4,883,147	\$6,600,553	\$11,483,700	14.5
Steam & Condensate Piping	\$1,312,869	\$1,776,589	\$3,099,458	3.9
Grand Total	\$38,801,014	\$40,643,956	\$79,444,970	100

Cost Impart • Total HVAC Cost • Break-down Material and Labor • Nan-Invasive Space IIVAC Cost • 05% of Total Bulding Area Non-Invasive Space • Assume 25% Extra Cost for Invasive Space • 4.0% of Total HVAC Cost is for Non-Invasive Space

	Non-Invas	we HVAC Cost		
Description				
Variable Frequency Drives	\$509,688	\$84,063	\$593,750	1.5
Hydronic Pamp Package	\$79,642	\$42,851	\$122,493	0.3
Condensate Pump Sets	\$15,518	\$5,407	\$20,924	0.1
Steam Specialties	\$268,506	\$194,448	\$462,965	1.2
VAV Boxes & Terminals	\$380,372	\$133,645	\$514,017	1.3
Fans & Accessories	\$251,891	\$47,801	\$299,692	0.8
Clean Steam Generators	\$67,043	\$14,723	\$81,760	0.2
Duct Humidifiers	\$20,501	\$4,199	\$24,700	0.1
Custom AlfUs	\$2,886,000	\$814,000	\$3,700,000	9.3
Ductwork	\$7,684,362	\$11,526,543	\$19,210,904	48.4
Controls	\$1,795,658	\$966,893	\$2,762,550	7.0
Mechanical Insulation	\$660,301	\$990,452	\$1,650,753	4.2
Test & Balance		\$362,500	\$362,500	0.9
Chilled Water Piping	\$1,683,021	\$945,890	\$2,628,911	6.6
Heating Hot Water Piping	\$2,441,574	\$3,300,277	\$5,741,850	14.5
Steam & Condensate Piping			\$1,544,729	3.9
	\$656,435	\$888,295		
Grand Total	\$19,400,507	\$20,321,978	\$39,722,485	100

Introduction Project Background Research Fortis Alternative Delivery Method Chilted Basen Court& Scientific In Concrete Over-pour Due to Steel Deflection

Research Focus Alternative Delivery Method

Conclusions Acknowledgements

Acknowled

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner April 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner 
 Durctwork

 75% Reduction in Cross-Section

 50% Reduction in Area > Material

 30% Savings in Labor

Material Cost Savings = \$7,684,362 x 0.5 = \$3,842,181 Labor Cost Savings = \$11,526,543 x 0.7 = \$8,068,580 Total Ductwork Cost = **\$11,910,761** 



# Research Focus Alternative Delivery Method

Conclusions Acknowledge

#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option April 14, 2009

Chilled Beams Cost & Schedule Impact (Mechanical)

 AHUs, Fans, Variable Frequency Drives

 • 75% Reduction in Capacity

 • P&K Estimate

 • 60% Material Savings

 • 40% Labor Savings

00: Labor Savings
 MUV Material Cos Savings - \$2,2866,000 x 0.4 - \$1,154,000 MUV Labor Cost Savings - \$2814,000 x 0.6 - \$488,100 Tonl AHU Cost Savings - \$251,801 x 0.4 - \$100,756 Fans Labor Cost Savings - \$257,801 x 0.06 - \$100,756 Fans Labor Cost Savings - \$257,801 x 0.06 - \$28,680 Tonl Fans Cost - **\$139,856** VPD Material Cost Savings - \$509,688 x 0.4 - \$203,875 VPD Labor Cost Savings - \$359,603 x 0.6 - \$30,438 Tonl VFD Cost - **\$254,818**

New Clinical Building Baltimore, MD Conclusions Acknowledgements Questions

#### Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

Johns Hopkins Hospital

 Chilled Water Piping

 • VAV Box Reheat Coll Piping

 • \$81.77.0

 • \$81.77.0

 • Analyze at Typ. Space

 • 2Pipe System in Interior (Cooling Only)

 • Arbyes System around Exterior (Cooling and Heating)

FFpc System atoma features
 Total Pipe per Area = 2.994 If = 14,364 SF = 0.21 If(SF Noninerasive Area = 1.6M SF x 6000 SF
 Cost of Chilled Water Pipe to Chilled Beam = 960,000 SF x 0.21 If(SF x S71.77/lf = 814,468,832

Chilled Beams Cost & Schedule Impact (Mechanical)

Add Chilled Water Pipe from Central Utility Plant to AHUs Total Cost of Chilled Water Piping = \$14,468,832 + \$2,628,911 - **\$17,097,743** 

# Concre Deflect Acknowled

#### Johns Hopkins Hospital

New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

#### Chilled Beams Cost & Schedule Impact (Mechanical)

 Chilled Beams

 Substitute Chilled Beams for VAV Boxes

 VAV Box Unit Coat = \$1,028,033 + 3,000 units = \$342,68 functiones diffusers)

 VAV rege Coat of Chilled Beam - \$140h (Source: Perces Associates)

 Average Coat of Installing Chilled Beam - \$140h (Source: Perces Associates)

Total Cost of Chilled Beams = 960,000 SF x \$3.81/SF = **\$3,657,600** 



# Conclusions Acknowledgements

#### Chilled Beams Cost & Schedule Impact (Mechanical)

- Chilled Beam HVAC System Initial Cost
   Chilled Beam HVAC System Initial Cost
   Add VAV and Chilled Beam Cost Together
   Total Savings in HVAC Cost = \$572,832
   Most of the Savings came from Labor
   Significant Savings in Durtwork
   Savings Offset by Increase Cost of Piping

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Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option

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# Introduction Answard Construction of Answard Construction Answard Construction of Answard Construction Answard

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Introduction
Project Background
Research Focus
Alternative Delivery Method
Concrete Over-pour Due to Steel Deflection
Acknowledgements
Ouestions

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner Anril 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

 Structural Steel Cost Impact

 • Columns can be Reduced by 1'-1"

 • 219 Columns per Floor

 • Average Weight = 91.6 lbs/ft.

Total Reduction in Steel = 219 col

Total Savings in Structural Steel = 120.3 tons x \$2,352/ton = \$288,092

# Project Backg arch Focus native Delive Acknowledg

Research Focus

Conclusions Acknowledgements

#### Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option

April 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical)

- Energy Swing

   • Estimated Annual HVAC Energy Cost = \$2.35 NF = \$3.760,000

   • JOYo of Load for Non-Invasive Space >> 50% of Energy Cost

   • Detailed Energy Modd Needed to Predift Energy Swings

   • Constitution Center Sware (23.85%

   • Industry Experts Predict 20.35% Savings

   • 3 Scenarios 15% 25%, and 35% Savings

   • Assume 3% Inflation

## 5 Year Savings for 15% Efficiency = \$1,497,176 5 Year Savings for 25% Efficiency = \$2,495,294 5 Year Savings for 35% Efficiency = \$3,493,411

10 Year Savings for 15% Efficiency = \$3,232,814 10 Year Savings for 25% Efficiency = \$5,388,023 10 Year Savings for 35% Efficiency = \$7,543,233

20 Year Savings for 1.5% Efficiency = \$7,577,446 20 Year Savings for 2.5% Efficiency = \$12,629,076 20 Year Savings for 3.5% Efficiency = \$17,680,706

30 Year Savings for 15% Efficiency = \$13,416,267 30 Year Savings for 25% Efficiency = \$22,360,445 30 Year Savings for 35% Efficiency = \$31,304,624

# Johns Hopkins Hospital

New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

#### Chilled Beams Cost & Schedule Impact (Mechanical)

 Space Savings

 • Reduce Mechanical Shaft Space by 50%

 • Reduce Mechanical Room Space by 25%

 • NCB Generates a Yearly Revenue of \$983/SF

Total Revenue Generated by Mechanical Shaft = 8,434 SF x \$983/SF/Year = \$8,280,792/Year

Total Revenue from Space Savings = \$8,280,792/Year + \$9,844,745/Year = \$18,125,537/Year

<u>Schedule Impact</u>

Analyze Typ. Floor
Baseline Schedule
Note the Amount of Float for Each Activity

Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger cetural Engineering, 5th Year uction Management Option

April 14, 2009

Baseline Typ, Floor Me Linum and the second 
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# Johns Hopkins Hospital

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Acknowledge

Question

#### Chilled Beams Cost & Schedule Impact (Mechanical)

Schedule Impact
Analyze Typ. Floor
Baseline Schedule
Note the Amount of Float for Each Activity

Install Durt Risers in Shafts - Decrease by 90%. Install Durt Mains - Docrease by 90%. Install HUXC Engineent - Decrease by 40%. Install Durt Branches - Dorrease by 40%. Install OH CHW RHHWS isom Mains - Delete Reheat Het Water (RHHW) and add 27.5%. Install OH CHW RHHWS isom RO - Delete Reheat Het Water and add 27.5%. Install OH CHW RHHWS isom RO - Delete Reheat Het Water and add 27.5%. Install OH CHW RHHWS isom RO - Delete Reheat Het Water and add 27.5%. Install OH CHW RHHWS isom RO - Delete Reheat Het Water and add 27.5%. Install OH CHW RHWS isom RO - Delete Reheat Het Water and add 27.5%.



New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

# Schedule Impact Activities that are accelerated are Ductwork and HVAC Equipment Critical Plati Acretities Floor by 31 Working Days Activities that Extend the Duration (Pping) are Absorbed in the Float Does, NA Accelerate the Overland Ployed Significantly Mechanical Overhead is Taken Off the Critical Path F Reduce Impact of Changes

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# Research Focus Alternative Delive Conclusions Acknowledge

Johns Hopkins Hospital New Clinical Building

Baltimore, MD Dan Weiger Architectural Engineering, 5<sup>th</sup> Year Construction Management Option

April 14, 2009

#### Chilled Beams Cost & Schedule Impact (Mechanical) Conclusion Violade Alternative to VAV Violade Alternative to VAV Condi Have Taken Mech, System Off Critical Path Project Worked Well for Chilled Beams Alsty of HVAC Cost was Dartwork Central Unling Plant Small Room Stores = 1 Chilled Beam/Room High Bearge Cost High Revenue per Area Many Assumptions More Research and Data Needed Johns Hopkins Hospital New Clinical Building Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option Conclusions Acknowledgements Questions Advisor: Dr. John I. Messner

#### Initial Savings

HVAC Savings = \$572,832 Façade Savings = \$2,351,760 Steel Savings = \$283,092 Total = \$8,207,684

#### Energy Savings

5 Year = \$1.5M - \$3.5M 10 Year = \$3.2M - \$7.5M 20 Year = \$7.6M - \$17.7M 30 Year = \$13.4M - \$31.3M

#### Revenue

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option

Deflection (S
 Problem Statement
 A Note CP-1
 Contractor Poured Concrete to FF Elevation
 Did Not Check Thickness (WerStick)
 Some Deflections of 2<sup>o</sup> Mid-Bay
 Contractor Responsible for all Over-pour
 Contractor Responsible for all Over-pour
 Overload the Floor
 Overload the Floor
 Door Jams

CAL ALL CREETERS ARS CONCERNMENT ATTAL COLLARD TRACCONSTRUCTOR BILL BE UNLIKED, AUGSSTOTCHER VOTE CONTRACTORS ALL SPERY THE ADMONAL CONSTRUCT REQUIRE TO LODGE DIE TO SCHEDTOR NOL CODEY THE REAM OF THE CONCERNE.

# April 14, 2009

# Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth)

 Goal
 Examine How the Constructor Over-pour Issue was Addressed in the Design, Bid, and Construction Phases
 Calculate Typical Bay Deflections

 • Calculate Typical Bay Deflections
 • Strategy for Addressing this Constructability Challenge on Future Projects



Research Focus Alternative Delivery Method Chilled Beams Cost & Schedule Impact

Conclusions Acknowledgements Questions

Research Focus Alternative Delivery Method Chilled Beams Cost & Schedule Impact

Conclusions Acknowledge

Johns Hopkins Hospital New Clinical Building Baltimore, MD

Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner

# Introduction Johns Hopkins Hospital Case Shady: Concrete Over-pour on Decks Due to Steel Network Johns Hopkins Hospital New Clinical Building, Network New Clinical Building, Bailmore, MU Schenkins Dun Weiger New Clinical Building, Network Dun Weiger New Clinical Building, Schenkins Dun Weiger New Clinical Weiger Advandigments April 14, 2007 New Clinical Weiger April 14, 2007 April 14, 2007 New Clinical Weiger



Johns Hopkins Hospital New Clinical Building Baltimore, MD

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Research Focus Alternative Delivery Method Chilled Beams Cost & Schedule Impact Design Phase
 Construction Load 85 PSF (Includes 7 PSF for Over-pour)
 Beam Max Deflection = 1.41" – 0.75" (Camber) = 0.66"



Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

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 Design Phase

 • Construction Load 85 PSF (Includes 7 PSF for Over-pour)

 • Beam Max Deflection = 1.41" - 0.75" (Camber) = 0.66"



#### Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth) Design Phase Construction Load 85 PSF (Includes 7 PSF for Over-pour) • Construction Load 85 DPSF (Includes 7 PSF for Over-pour) • • Beam Max Deflection = 1.41" • 0.75" (Camber) = 0.66" • • Girder Max Deflection = 0.99" • Johns Hopkins Hospital New Clinical Building Baltimore, MD arch Focus native Deliv Delivery Method ns Cost & Schedule Impas Dan Weiger Architectural Engineering, 5th Year Construction Management Option Advisor: Dr. John I. Messner w24033 on = 0.85 ce = 0.15" th Reducing Ceiling Ple



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 Design Phase

 • Construction Load 85 PSF (Includes 7 PSF for Over-pour)

 • Beam Max Deflection = 1.41° - 0.75° (Camber) = 0.66°

 • Girder Max Deflection = 0.99°

 • Total Mid-Bay Deflection = 0.66° + 0.99° - 1.65°



# Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth)

 Design Phase
 Deficience of the phase of the

 $\begin{array}{l} 56.5 \mathrm{fi}^3/(28.667)^2-0.07^*-7/8^*\\ \mathrm{Total SF \ of Building}=1.5 \mathrm{M}\\ \mathrm{Total Concrete \ Over-Pour=1,500,000\ SF x\ 0.07^*=103,128\ \mathrm{fi}^3=3,820\ \mathrm{CY} \end{array}$ 



Johns Hopkins Hospital New Clinical Building Baltimore, MD Research Focus Alternative Delivery Method Chilled Beams Cost & Schedule Impact

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#### Johns Hopkins Hospital New Clinical Building Baltimore, MD

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# Bid Phase • Clark/Banks Alerted Sub of Note CP4 • Never Contacted or Asked Question about Anticipated Deflection • Assumed Took Extra Concrete • Carried an Allowance of \$100,000 for Reshore and Flash Patching

# Case Study: Concrete Over-pour on Decks Due to Steel Deflection (Structural Breadth)

Johns Hopkins Hospital New Clinical Building Baltimore, MD

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Construction Phase • Clark/Banks held Pre-Con Meeting with Concrete Sub > Structural Engineer Did Not Attend • 3 Options to Address Deflection > Shore Steel > Pour to Taickness then Flash Patch > Dour to Taickness then Flash Patch

- Pour to Level and Pay for Extra Concrete
   1,200 CY of Over-pour = \$100,000
   Used Reshore and Flash Patching Allowance to Cover Cost
   Typical Deflection was 1-1/2" Mid-Bay

#### Johns Hopkins Hospital New Clinical Building

Baltimore, MD

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April 14, 2009

- Conclusion

   • IF I, see Notes Similar to CP-4 Should be Clearly Called Out on DWGs and Specs

   • CM Should Contact Structural Engineer for Expected Deflections

   • Carry an Allowate for Overpour

   • Ibilings only Struct Faul II. Requirements Should Consult CM for Constructability

   • Survey Defactions

   • Che Changer in Should Field

   • Allow Date Cristion in MEP Coordination

   • Integrated Team Approach would be Very Helpful

# Alternative Delivery Method Chilled Beams Cost & Schedule Impact

Research Focus Alternative Delivery Method

Conclusion

Concrete Over-pour Due to Steel Deflection

Acknowledgements Questions

### Johns Hopkins Hospital

New Clinical Building Baltimore, MD Dan Weiger Architectural Engineering, 5th Year Construction Management Option

#### Advisor: Dr. John I. Messner

#### Conclusions

Alternative Delivery Method A traditional delivery method with early procurement, a project manager, integrated project delivery priori plasmaged the rest more efficiently.

Chilled Beams Cost & Schedule Impact The Chilled Beam IIVAC system used in non-invasive spaces could save \$3,207,684 initially and an additional \$13, AV as 31, AV aver a 300 year life-cycle. It would also allow JHH to generate an additional income of \$18,125,507 per year. This would take the mechanical overhead off the critical path of the building schedule. This system would be able to absorb namy of the changes and edapsy encountered thins far on the NCE project.

Case Study: Concrete Over-pour on Decks Due to Steel Deflection A failure to communicate early in the design, bid, and construction places put the concrete contractor at financial risk. The NCB project head a strick levelness specification that required the contractor to over-pour the decks. The result was 1,200 CV of extra concrete that amounted to \$100,000 of exposure to the concrete contractor. Further projects can avoid this problem by working with the survetural expineer to determine the expected deflections. An allowance should be carried by the contractor to avoid the financial risk associated with this problem.

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Introduction Project Background Research Focus Alternative Delivery Method Childled Beams Cost & Schechke Impact	Johns Hopkins Hospital New Clinical Building Baltimore, MD Dan Weiger Architectural Enamescine, 5 <sup>th</sup> Your	Clark Construction Group Mike Hartman Joe Salerno Marty McMahon Jim Salerno Jim Kinkead Katte Tworney Rohin Givens John Bond Brian Fleed	Penn State University Dr. Michael Horman Dr. John Messner Dr. David Riley Dr. Moses Ling Dr. Linda Hanagan <u>United Sheet Metal</u> Mike Topper	<u>MC Dean</u> Bill Knot <u>TROX USA</u> Ken Loudermilk Chris Lawrence <u>DADANCO</u> Bill Rafferty
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