



# **The Northeastern Pennsylvania Office Building**



**Christopher Havens**

**Penn State AE Senior Capstone Project**

Construction Management

Spring 2012

Dr. Chimay Anumba – CM Advisor

The Northeastern Pennsylvania Office Building

Christopher Havens | Construction Management

The Northeastern Pennsylvania Office Building

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**Presentation Outline**

- I. Project Background
- II. Analysis 1: Replacing the PEMB
  - I. Structural Breadth
- III. Analysis 2: Design-Build Phase 2 & 3
- IV. Analysis 3: Horizontal Expansion vs. Vertical Expansion
- V. Analysis 4: Geothermal System
  - I. Mechanical Breadth
- VI. Recommendations
- VII. Acknowledgements



## Project Background

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### Building Information:

- Anonymous Project – Owner's Request
- Phase 1 of Multi-Phase Project
- \$ 5.4 Million
- June 2011 – March 2012
- Two Buildings
  - Office Building: ~11,000 SF
    - 50 Employees
  - Shop Building: ~14,000 SF
    - 4 Work Bays, 1 Wash Bay
- Design-Bid-Build



## Replacing the Pre-Engineered Metal Building

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Pre-Engineered Metal Building

### Reason for Analysis:

- PEMB for Industrial/Commercial Project... But Why?
  - Cost?
  - Schedule?
  - Ease of Construction?
- How Do Other Structural Systems Compare?
  - Standard Steel
  - Cast-In-Place Concrete
  - Tilt-Up Concrete



Standard Steel



Cast-In-Place Concrete



Tilt-Up Concrete



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Pre-Engineered Metal Building

### Criteria for Study:

- Schedule & Cost
- Constructability
- Regional Constraints
  - Delivery Issues
  - Weather Constraints
  - Typical Construction Projects
- Impact on Other Building Systems
- Environmental Impact

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Pre-Engineered Metal Building

### Criteria for Study:

- Schedule & Cost
- Constructability
- Regional Constraints
  - Delivery Issues
  - Weather Constraints
  - Typical Construction Projects
- Impact on Other Building Systems
- Environmental Impact

### Results:

- No Major Advantages/Disadvantages
- Schedule & Cost
- Constructability
- Impacts on Other Building Systems

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Pre-Engineered Metal Building

### Results:

#### Regional Constraints

- Higher \$ to Heat Concrete
  - Cast-In-Place
  - Tilt-Up
- Common Structures in Area
  - Steel

#### Environmental Impact

- Fewer Harmful Emissions
  - Steel
- Lesser Depletion of Natural Resources
  - Steel

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Pre-Engineered Metal Building

### Results:

#### Regional Constraints

- Higher \$ to Heat Concrete
- Cast-In-Place ❌
- Tilt-Up ❌

- Common Structures in Area
- Steel ✓

#### Environmental Impact

- Fewer Harmful Emissions
- Steel ✓
- Lesser Depletion of Natural Resources
- Steel ✓



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### Results:

#### Regional Constraints

- Higher \$ to Heat Concrete
- Cast-In-Place ❌
- Tilt-Up ❌

- Common Structures in Area
- Steel ✓

#### Environmental Impact

- Fewer Harmful Emissions
- Steel ✓
- Lesser Depletion of Natural Resources
- Steel ✓

### Results:

	Standard Steel	Cast-In-Place Concrete	Tilt-Up Precast Concrete
Schedule & Cost	X	X	X
Constructability	X	X	X
Regional Constraints	X		
Impact on Other Building Systems	X	X	X
Environmental Impact	X		



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Pre-Engineered Metal Building

### Results:

#### Regional Constraints

- Higher \$ to Heat Concrete
- Cast-In-Place ❌
- Tilt-Up ❌

- Common Structures in Area
- Steel ✓

#### Environmental Impact

- Fewer Harmful Emissions
- Steel ✓
- Lesser Depletion of Natural Resources
- Steel ✓

### Results:

	Standard Steel	Cast-In-Place Concrete	Tilt-Up Precast Concrete
Schedule & Cost	X	X	X
Constructability	X	X	X
Regional Constraints	X		
Impact on Other Building Systems	X	X	X
Environmental Impact	X		

**Best Alternate Structure: Standard Steel**



## Structural Breadth

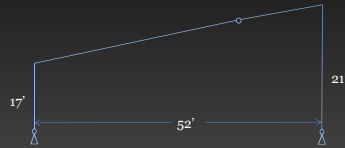
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Pre-Engineered Metal Building

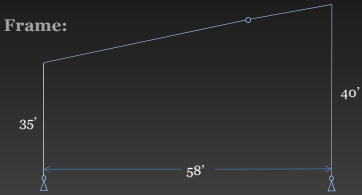
### Office Frame:



Superimposed – 2.69 PSF  
Collateral – 10.0 PSF  
Snow – 30.0 PSF  
Self-Weight (Assumed) – 8.0 PSF

Tributary Width: 24'

### Shop Frame:



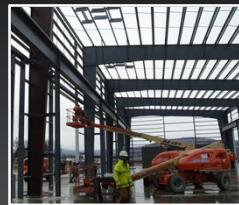
Superimposed – 3.52 PSF  
Collateral – 10.0 PSF  
Snow – 30.0 PSF  
Self-Weight (Assumed) – 8.0 PSF

Tributary Width: 40'



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Pre-Engineered Metal Building

Load Combination:

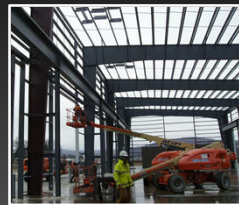
$$1.2D + 1.6S$$



## Structural Breadth

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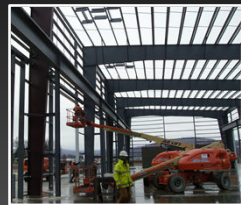
### Building Loads:

Multiply by Trib. Area to Find Distributed Load

## Structural Breadth

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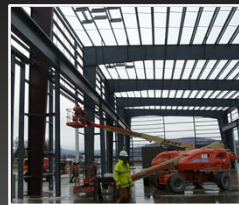
### Reactions:

Use Free Body Diagrams to Sum Forces & Moments

## Structural Breadth

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Pre-Engineered Metal Building

#### Load Combination:

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#### Building Loads:

Multiply by Trib. Area to Find Distributed Load

#### Reactions:

Use Free Body Diagrams to Sum Forces & Moments

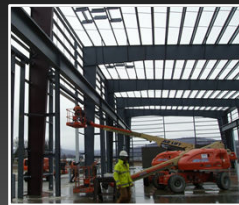
#### Max. Shear & Moment:

Use FBD's to Sum Forces & Moments on Each Member

## Structural Breadth

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Pre-Engineered Metal Building

#### Load Combination:

$1.2D + 1.6S$

#### Building Loads:

Multiply by Trib. Area to Find Distributed Load

#### Reactions:

Use Free Body Diagrams to Sum Forces & Moments

#### Max. Shear & Moment:

Use FBD's to Sum Forces & Moments on Each Member

#### Size Members:

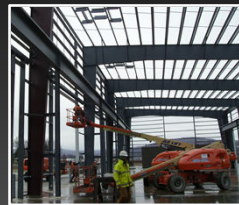
Use Steel Manual Values to Determine Size of Each Member



## Structural Breadth

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Pre-Engineered Metal Building

#### Load Combination:

1.2D + 1.6S

#### Building Loads:

Multiply by Trib. Area to Find Distributed Load

#### Reactions:

Use Free Body Diagrams to Sum Forces & Moments

#### Max. Shear & Moment:

Use FBD's to Sum Forces & Moments on Each Member

#### Size Members:

Use Steel Manual Values to Determine Size of Each Member

#### Estimate Cost & Schedule:

Use RS Means Building Construction Cost Data 2012

#### Included in Structural Steel Estimate:

- Steel Members
- Bolts
- Base Plates
- Purlins
- Metal Siding/Roofing

#### NOT Included in Estimate:

- Design Fees
- Fabrication Fees
- Documentation Fees



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Pre-Engineered Metal Building

### Results:

	PEMB	Structural Steel
Schedule	June 14– Nov. 16	June 14– Nov. 4
Cost	\$661,500	\$682,500

Note: Structural Steel Estimate Does Not Include:

- > Design Fees
- > Fabrication Fees
- > Documentation Fees

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### Results:

	PEMB	Structural Steel
Schedule	June 14– Nov. 16	June 14– Nov. 4 ✓
Cost	\$661,500	\$682,500 ⚠

Note: Structural Steel Estimate Does Not Include:

- Design Fees
- Fabrication Fees
- Documentation Fees

### Conclusion:

- Steel (Without Fees) is \$21,000 > PEMB
- Steel is 8 Days < PEMB

PEMB Should **NOT** Be Replaced By Standard Steel Structure  
*Schedule Acceleration is Not Expected to Cover Additional Cost*



## Design-Build Phase 2 & 3

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### Reason for Analysis:

- Phase 2 & 3 are Nearly Identical to Phase 1
- Could Later Phases Be Design-Build?
- If So, What are the Benefits?

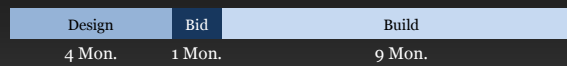


### Design-Build Phase 2 & 3

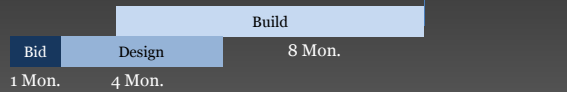
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#### Design-Bid-Build:



#### Design-Build:

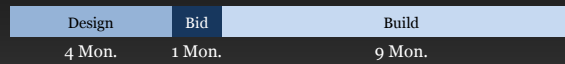


### Design-Build Phase 2 & 3

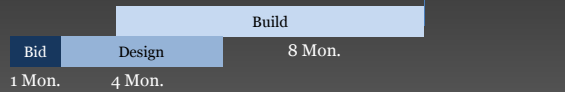
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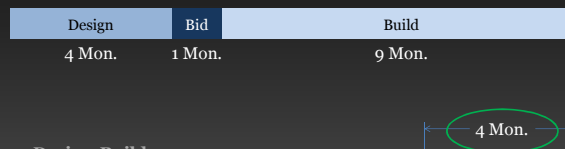


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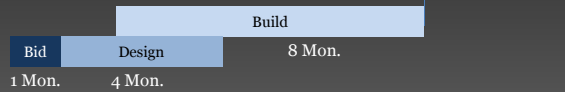
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#### Design-Bid-Build:



#### Design-Build:



#### Conclusion:

- Each Phase Accelerated About 4 Months
- Fewer Change Orders ✓
- Earlier Turnover Date ✓
- Increased Revenue for Owner ✓

Phase 2 & 3 **SHOULD** Be Delivered as Design-Build Projects



## Horizontal Expansion vs. Vertical Expansion

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Original Building

### Reason for Analysis:

- Schematic Phase of Design
- Owner Wants to Double the Size of the Office Building
- Two Options for Expansion
  - Horizontal
  - Vertical

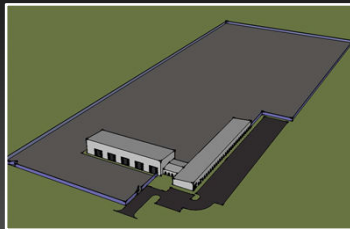
### Criteria for Study:

#### Based on Owner Interview:

1. Schedule Impacts
2. Project Cost Impacts
3. Limiting Change Orders
4. Functionality
5. Aesthetics



## Horizontal Expansion vs. Vertical Expansion



Horizontal Expansion

### Schedule:

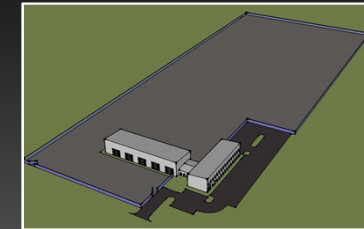
- Horizontal
  - June 14– Dec. 7
- Vertical
  - June 14– Nov. 23

### Project Cost:

- Horizontal
  - \$176,000
- Vertical
  - \$231,000

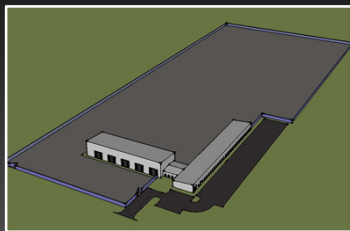


Original Building



Vertical Expansion

### Horizontal Expansion vs. Vertical Expansion



Horizontal Expansion

Schedule:

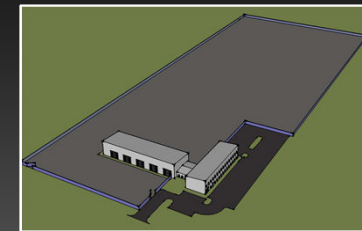
- Horizontal
  - June 14– Dec. 7 ❌
- Vertical
  - June 14– Nov. 23 ✓

Project Cost:

- Horizontal
  - \$176,000 ✓
- Vertical
  - \$231,000 ❌



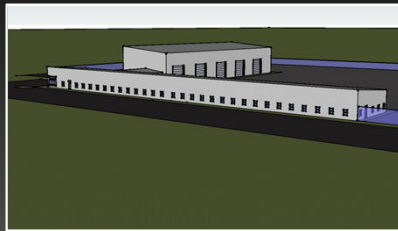
Original Building



Vertical Expansion



## Horizontal Expansion vs. Vertical Expansion



Horizontal Expansion

### Limiting Change Orders:

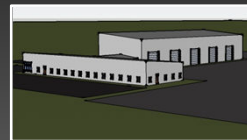
- Repetition of Work
- Horizontal

### Functionality:

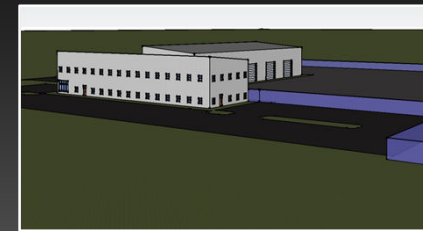
- Elongated Floorplan
- Horizontal
- Stacked Floorplan
- Vertical

### Aesthetics:

- More Traditional
- Vertical

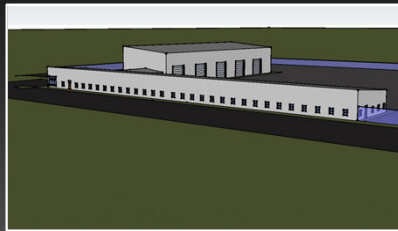


Original Building



Vertical Expansion

## Horizontal Expansion vs. Vertical Expansion



Horizontal Expansion

### Limiting Change Orders:

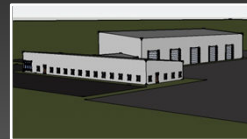
- Repetition of Work
- Horizontal ✓

### Functionality:

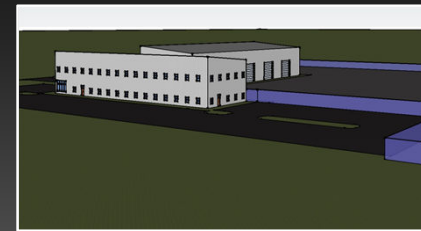
- Elongated Floorplan
- Horizontal ✗
- Stacked Floorplan
- Vertical ✓

### Aesthetics:

- More Traditional
- Vertical ✓



Original Building

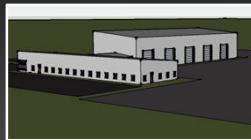


Vertical Expansion

## Horizontal Expansion vs. Vertical Expansion

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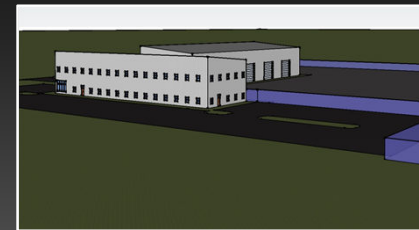
Original Building

### Conclusion:

Owner's Priorities	Horizontal	Vertical
Schedule Impacts		X
Project Cost Impacts	X	
Limiting Change Orders	X	
Functionality		X
Aesthetics		X

### **VERTICAL EXPANSION** Should Be Chosen

*Shorter Schedule (#1 Owner Priority)  
More Pleased Employees (Functionality & Aesthetics)*



Vertical Expansion



## Geothermal System

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### Reason for Analysis:

- Geothermal System in Shop Building
  - Replace Gas-Fired Heaters
- Environmentally Friendly



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  - Replace Gas-Fired Heaters
- Environmentally Friendly



Loop System



Heat Exchanger



Chilled Beams

### System Components (From Mech. Breadth):

- Horizontal Closed Loop System
  - ~4,000 FT Buried 5 FT Below Grade
- 20 TON ( 200 MBH) Heat Exchanger
- Terminal Units
  - 'Chilled Beams'



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### Cost & Schedule:

	Natural Gas	Geothermal
Cost	\$22,000	\$41,000
Schedule	2 Weeks	5 Weeks

\*Derived Using RS Means Building Construction Cost Data 2012

### Additional Factors:

- Payback Period
  - Low Price of Natural Gas
- Cooling
  - Overhead Doors
- Fewer Emissions





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- III. Analysis 2: Design-Build Phase 2 & 3
- IV. Analysis 3: Horizontal Expansion vs. Vertical Expansion
- V. **Analysis 4: Geothermal System**
  - I. Mechanical Breadth
- VI. Recommendations
- VII. Acknowledgements

### Cost & Schedule:

	Natural Gas	Geothermal
Cost	\$22,000	\$41,000 ❌
Schedule	2 Weeks	5 Weeks ❌

\*Derived Using RS Means Building Construction Cost Data 2012

### Additional Factors:

- Payback Period
  - Low Price of Natural Gas ❌
- Cooling
  - Overhead Doors ❌
- Fewer Emissions ✓



## Geothermal System

### Presentation Outline

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### Conclusion:

- Geothermal System
  - More Expensive
  - Longer Schedule
- Payback Period Does Not Justify Cost
- Owner Will Not Want to Reduce Demand of Natural Gas

Geothermal System Should **NOT** Be Chosen



## Recommendations

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#### Replacing the PEMB:

- Do Not Replace PEMB Structure

#### Design-Build Phase 2 & 3:

- Deliver Phase 2 & 3 as Design-Build Projects

#### Horizontal Expansion vs. Vertical Expansion:

- Choose Vertical Expansion Option

#### Geothermal System:

- Do Not Replace Gas Heaters with Geothermal System



## Acknowledgements

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[VII. Acknowledgements](#)

Thank You:

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## Questions?

