Library In Metropolitan Washington, D.C.
Penn State Architectural Engineering Senior Capstone Project
Lowell Stine | Construction | Rob Leicht
Project Introduction

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Library In Metropolitan Washington, D.C.

Outline
- Project Introduction
- Early Involvement
- Caisson Rebar Cage Prefab
- Structural Sequencing
- Structural Breadth
- Mechanical Room
- Acoustical Breadth
- Summary of Conclusions
- Acknowledgments

Picture Provided by Multivista
Building Name: Library in Metropolitan Washington, D.C.
Location: Metropolitan Washington, D.C. (Undisclosed)
Occupant: County Library & Non-profit Art Group
Function Types: A-3 (Assembly), B (Business), M (Mercantile)
Gross Area: 90,000 ft²
Number of Stories: Five Plus Basement
Project Delivery: Design-Bid-Build
Construction Dates: January 2013 – October 2014
Project Cost: $69.5 Million

Project Team

Owner: Undisclosed County
Construction Manager: MBP
Civil Engineer: ADTEK
Architect: The Lukmire Partnership
Mechanical & Plumbing Engineer: Mendoza, Ribas, Farinas & Associates
Landscape Architect: Parker Rodriguez
Contractor: Costello Construction
Electrical Engineer: Mendoza, Ribas, Farinas & Associates
Interior Design: The Studio of Sandra Ragan
Structural Engineer: Columbia Engineering
IT/Security: Wright Engineering
Lighting Consultant: MCLA

Acknowledgments
Project Introduction

Library In Metropolitan Washington, D.C.

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Systems

Architectural:
- 50’ Cantilever of 3rd thru 5th Floors
- Exposed Structure in Library Space

Structure:
- Concrete Caissons
- Structural Steel
- Composite Slabs

Building Enclosure:
- 53% Curtain Wall – UV Protection
- Terra Cotta Panels
- Architectural CMU’s

Mechanical:
- IPEC (Integrated Packages Equipment Center)
- Hydronic In-Slab Heating

Picture Courtesy of The Lukmire Partnership, Inc.

Picture Provided by http://www.syetecon.com

Picture Provided by Multivista
Measurable Success

1) Minimize costs and schedule delays from change orders and rework

2) Minimize wasted material and labor costs and limit schedule delays

3) Shorten structural erection durations

4) Cost effectiveness and fewer constructability challenges

Early Involvement in Design Research Analysis

Caisson Rebar Cage Fabrication Analysis

Structural Sequencing Analysis

Mechanical Penthouse vs. IPEC Analysis

Acoustical Breadth
Early Involvement in Design Research Analysis
Goal

Considerations / Requirements
Specifics of this Project
Typical Problem Areas
Early Involvement in Design Research Analysis

Lowell Stine | Construction

Library In Metropolitan Washington, D.C.

Goal
- Considerations / Requirements
- Specifics of this Project
- Typical Problem Areas

Industry Member Interviews
- Scopes
- Benefits
- Owner Buy-in
- Future

<table>
<thead>
<tr>
<th>#</th>
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Early Involvement in Design Research Analysis

Lowell Stine | Construction

Library In Metropolitan Washington, D.C.

**Goal**
Considerations / Requirements
Specifics of this Project
Typical Problem Areas

**Industry Member Interviews**
Scopes
Benefits
Owner Buy-in
Future

**Mind Maps**
Show Topics
Trace Patterns

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Early Involvement in Design Research Analysis

Overall Conclusions
- Smooth Transition Between Phases
- Early Cost Influence

Influence of Cost Curve
- High
- Low
- Close-out
- Completion

Process Flow
- Programming
- Design
- Procurement
- Construction

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# Early Involvement in Design Research Analysis

**Results**

- Earlier Involvement is Beneficial
- Less Change Orders
- Cost Savings
- Funding Issues

Scope Selection (Project Specific)

<table>
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<tr>
<th>Scopes</th>
<th>Program</th>
<th>Conceptual</th>
<th>Schematic Design</th>
<th>Sub-Selection &amp; Design Input</th>
<th>Sub-Selection &amp; Design Input</th>
<th>Design Input &amp; Long Lead Items</th>
<th>Construction Documents</th>
<th>Construction</th>
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</table>

**Scopes**
- Program
- Conceptual
- Schematic Design
- Sub-Selection & Design Input
- Sub-Selection & Design Input
- Design Input & Long Lead Items
- Construction Documents
- Construction

**Rating Scale**

- **Owner**
  - X
  - CM
  - Contractor
  - Design Team

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<th>Resources Available</th>
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**Summary of Conclusions**
Caisson Rebar Cage Fabrication Analysis
Goal

Determine Appropriate Fabrication Method
Cost Savings
Scheduled Reduction
## Goal

Determine Appropriate Fabrication Method

Cost Savings

Scheduled Reduction

## Background

9 Caisson Types (48 Total)

Prefab to Planned Length

Planned Lengths Incorrect

15 Day Delay

<table>
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<th>Qty of Vertical Rebar</th>
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## Outline

- Project Introduction
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Goal

Determine Appropriate Fabrication Method
Cost Savings
Scheduled Reduction

Background

9 Caisson Types (48 Total)
Prefab to Planned Length
Planned Lengths Incorrect
15 Day Delay

Fabrication Methods

100% Planned
Planed + 10%
80% of Planned
10’ Sections
15’ Sections

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Outline

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Results

30' Max Cage Length
Outline

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Results

30’ Max Cage Length
Truck Crane Installation
Concrete Pump Placement
Caisson Rebar Cage Fabrication Analysis

Results

30’ Max Cage Length
Truck Crane Installation
Concrete Pump Placement
High Splice Costs
Cut-off Higher Productivity

Outline

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Caisson Rebar Cage Fabrication Analysis

**Results**

- **30' Max Cage Length**
- **Truck Crane Installation**
- **Concrete Pump Placement**
- **High Splice Costs**
- **Cut-off Higher Productivity**
- **Use 100% Prefabricated Method**
- **Accept Unknowns**

### Prefabrication Option Comparison

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<th>Caisson Types</th>
<th>Base Line</th>
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Structural Sequencing Analysis
Goal
Reevaluate Structural Sequence
Save Erection Costs
Shorten Erection Schedule

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Save Erection Costs
Shorten Erection Schedule

Background Information
Current Erection
Complex Erection Sequence
5 Week Delay
Structural Sequencing Analysis

Outline

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Shoring Sequence

Linear
Structural Sequencing Analysis

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Shoring Sequence

Linear
4-D Comparisons
Slabs After Shoring
Hanger Resizing?
Structural Sequencing Analysis

Complexity of Erection

- Complex structure
- Inconsistent erection sequence
Complexity of Erection
Complex structure
Inconsistent erection sequence

Site
Very urban site
Shoring will occupy large area
Tight delivery scheduling
**Complexity of Erection**

Complex structure
Inconsistent erection sequence

**Site**

Very urban site
Shoring will occupy large area
Tight delivery scheduling

**Safety**

High priority
Dangerous welding locations
OSHA compliance

Picture Provided by Multivista
## Complexity of Erection
Complex structure
Inconsistent erection sequence

## Site
Very urban site
Shoring will occupy large area
Tight delivery scheduling

## Safety
High priority
Dangerous welding locations
OSHA compliance

## Trade Integration
Delay of MEP rough-in start-up

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<th>MEP Rough-in Start Dates</th>
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Structural Breadth - Shoring Design

Required Shoring Load

Dead Loads
Live Loads

\[ P_{u} = 291 \text{ psf} \]

\[ L = L_{0} \times \left( \frac{0.4}{0.25 + \frac{15}{\sqrt{K_{L}L_{A}T}}} \right) \]

\[ P_{u} = 1.2D + 1.6L \]
Structural Breadth - Shoring Design

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Required Shoring Load

Dead Loads
Live Loads
P_u = 291 psf

Picking Shoring System

Mabey’s Mass Series
Shoring Towers

Required Shoring Load

\[ L = L_0 \times \left( 0.4 + \frac{15}{0.25 \sqrt{K_L A_T}} \right) \]

\[ P_u = 1.2D + 1.6L \]

Picture Provided by Mabey Inc.
Required Shoring Load

- Dead Loads
- Live Loads
- \( P_u = 291 \text{ psf} \)

Picking Shoring System

- Mabey’s Mass Series
- Shoring Towers

Finalize Shoring Design

- Mass 25 - 100 kips
- Space at 20’x18’
  - (16) 5’x5’ & (2) 5’x10’

\[ L = L_0 \times \left( 0.4 + \frac{15}{0.25 + \sqrt{K_L A_T}} \right) \]

\[ P_u = 1.2D + 1.6l. \]
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Structural Breadth - Shoring Design

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Required Shoring Load
Dead Loads
Live Loads
P_u = 291 psf

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Mabey's Mass Series
Shoring Towers

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Space at 20'x18'
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Structural Sequencing Analysis

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3 Week Schedule Savings (with shoring install)

$30,000 Savings

Better Productivity (Specific Zones)

Recommend the Shoring Sequence

IPEC vs. Mechanical Penthouse

Criteria & Categories

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Steel Erection Start

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<td>$1357</td>
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<td>Every Week After for 4 Weeks</td>
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Total Estimated Costs Savings

$30,000

Total Duration (weeks)

Structure Complete Milestone

Shoring Cost Break Down

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Structure Duration Comparisons

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<td>Structure Complete Milestone</td>
<td>1/1/14</td>
<td>3/7/14</td>
<td>2/13/14</td>
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</tbody>
</table>

IPEC vs. Mechanical Penthouse

Criteria & Categories

Top
- Constructability
- Schedule
- Cost
- Site
- Safety
- Other Trades

Shoring
- Constructability
- Schedule
- Cost
- Site
- Safety
- Other Trades
Mechanical Penthouse vs. IPEC Analysis
Goals

IPEC & Penthouse Differences
How to Choose Which to Use
Gain Knowledge of Each
Goals

IPEC & Penthouse Differences
How to Choose Which to Use
Gain Knowledge of Each

IPEC
Prefabricated Equipment Module
4' CMU Base Wall
One Supplier
Goals

IPEC & Penthouse Differences
How to Chose Which to Use
Gain Knowledge of Each

IPEC

Prefabricated Equipment Module
4’ CMU Base Wall
One Supplier

Mechanical Penthouse

Site Constructed
On Concrete Structural Roof
Multiple Different Suppliers

Picture Provided by http://www.jetsongreen.com/
Acoustical Breadth

Project Introduction

Early Involvement

Caisson Rebar Cage Prefab

Structural Sequencing

Structural Breadth

Mechanical Room

Acoustical Breadth

Summary of Conclusions

Acknowledgments

Acoustical Impacts of IPEC and Penthouse

Library Spaces

Outdoor Environment

Differences

Similar Acoustical Properties

Over Estimates
### Acoustical Impacts of IPEC and Penthouse Library Spaces

#### Differences
- Similar Acoustical Properties
- Over Estimates

#### Recommendations
- IPEC Would Be More Desirable

<table>
<thead>
<tr>
<th></th>
<th>Limit</th>
<th>Actual</th>
</tr>
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<tbody>
<tr>
<td>Conference Room</td>
<td>35 dB</td>
<td>37 dB</td>
</tr>
<tr>
<td>Property Line</td>
<td>55 dB</td>
<td>57 dB</td>
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</table>
## Results

1 Week On Site vs. 10.5 Weeks On Site  
Potential $1 Million Savings  
Flexible Design  
Penthouse  
Design-Build Package

### IPEC vs. Mechanical Penthouse Schedule

<table>
<thead>
<tr>
<th>System</th>
<th>Lead Time</th>
<th>Site Install Time</th>
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<tr>
<td>IPEC</td>
<td>1 Long Lead Item (Months)</td>
<td>1 Week</td>
</tr>
<tr>
<td>Penthouse</td>
<td>Multiple Shorter Lead Times (Weeks)</td>
<td>10.5 Weeks</td>
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### IPEC vs. Mechanical Penthouse Costs

<table>
<thead>
<tr>
<th>System</th>
<th>Equipment</th>
<th>Enclosure/Structure</th>
<th>Total</th>
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<tr>
<td>IPEC</td>
<td>$5,800,000</td>
<td>$50,000</td>
<td>$5,850,000</td>
</tr>
<tr>
<td>Penthouse</td>
<td>$4,880,000</td>
<td>$100,000</td>
<td>$4,880,000</td>
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</table>

### IPEC vs. Mechanical Penthouse

<table>
<thead>
<tr>
<th>Criteria &amp; Categories</th>
<th>IPEC</th>
<th>Penthouse</th>
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<tbody>
<tr>
<td>Acoustical</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Maintenance</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Flexibility in Design</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Responsibility</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Constructability</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Costs</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Schedule</td>
<td>✓</td>
<td>x</td>
</tr>
</tbody>
</table>
Conclusions

Lowell Stine | Construction

Library In Metropolitan Washington, D.C.

Outline
Project Introduction
Early Involvement
Caisson Rebar Cage Prefab
Structural Sequencing
Structural Breadth
Mechanical Room
Acoustical Breadth
Summary of Conclusions
Acknowledgments

Design (Early Involvement)
Foundation (100% Prefabrication Cage Length)
Structure (Shoring Sequence)
Building Systems (Mechanical Penthouse)

Early Involvement
Undetermined Cost Savings
Undetermined Schedule Savings

100% Prefabrication Cage Length
$0.00 Savings
Account for Caissons in Schedule

Shoring Sequence
$30,000 Savings
3 Week Schedule Savings

Mechanical Penthouse
Possible $1 Million Savings
Additional 9.5 Week Mechanical Schedule
Acknowledgments

Academic
Michelle Vigeant
Moses Ling
Dr. Robert Leicht
Kevin Parfitt
Ray Sowers

Special Thanks
Library’s Owner
PACE Industry Members
Matt Strevig
Friends and Family
## Structural Analysis

### Library in Metropolitan Washington, D.C.

#### Shoring Sequence Schedule

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start Date</th>
<th>Duration</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Initial Setup</td>
<td>1/1/2021</td>
<td>1 week</td>
<td>$10,000</td>
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<tr>
<td>Fencing Installation</td>
<td>1/8/2021</td>
<td>2 weeks</td>
<td>$20,000</td>
</tr>
<tr>
<td>Excavation</td>
<td>1/20/2021</td>
<td>3 weeks</td>
<td>$30,000</td>
</tr>
<tr>
<td>Steel Frame Installation</td>
<td>2/5/2021</td>
<td>4 weeks</td>
<td>$40,000</td>
</tr>
<tr>
<td>Concrete Pour</td>
<td>3/5/2021</td>
<td>5 weeks</td>
<td>$50,000</td>
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</table>

#### General Conditions Costs

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Management</td>
<td>Landscaping</td>
<td>$5,000</td>
</tr>
<tr>
<td>Office Services</td>
<td>Printing</td>
<td>$3,000</td>
</tr>
<tr>
<td>Security</td>
<td>Surveillance</td>
<td>$2,000</td>
</tr>
<tr>
<td>Project Management</td>
<td>Travel</td>
<td>$6,000</td>
</tr>
<tr>
<td>Project Closeout</td>
<td>Insurance</td>
<td>$4,000</td>
</tr>
<tr>
<td>Final Audit</td>
<td>Legal Fees</td>
<td>$8,000</td>
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**Total General Condition Costs:** $25,000
Dead Load Calculations

<table>
<thead>
<tr>
<th>Description</th>
<th>Index</th>
<th>RLF</th>
<th>LB/FL</th>
<th>RLF/FL</th>
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<tbody>
<tr>
<td>Colonnade</td>
<td>W14x122</td>
<td>.82</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Trusses</td>
<td>W14x123</td>
<td>.83</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>End Truss</td>
<td>W14x123</td>
<td>.83</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>2nd Floor Order</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>3rd Floor Order</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>4th Floor Order</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>5th Floor Beams</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
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<tr>
<td>Roof Floor Beams</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Decking</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Total Dead Load (lb/ft²) = 70

---

Live Load Calculations

\[
\text{Total Dead Load} = \text{Dead Load} + \text{Shoring Load}\]

<table>
<thead>
<tr>
<th>Description</th>
<th>Index</th>
<th>RLF</th>
<th>LB/FL</th>
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<tr>
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<td>2.2</td>
</tr>
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<td>40000</td>
<td>2.2</td>
</tr>
<tr>
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</tr>
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</tr>
<tr>
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<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Decking</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Total Dead Load (lb/ft²) = 70

---

Live Load & Factored Loads

<table>
<thead>
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<th>RLF</th>
<th>LB/FL</th>
<th>RLF/FL</th>
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</thead>
<tbody>
<tr>
<td>Colonnade</td>
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<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Trusses</td>
<td>W14x123</td>
<td>.83</td>
<td>40000</td>
<td>2.2</td>
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<tr>
<td>End Truss</td>
<td>W14x123</td>
<td>.83</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
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<td>2.2</td>
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<td>2.2</td>
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<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Roof Floor Beams</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
<tr>
<td>Decking</td>
<td>W12x125</td>
<td>.84</td>
<td>40000</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Total Dead Load (lb/ft²) = 70

---

Live Load Assumptions

- Started with 50 psf
- Four floors is 200 psf
- In live load reduction total is 129 psf
- Factored live load would then be 206 psf
  (This would be an acceptable live load on four floors of only structure)
## Zone 2 Acoustics

<table>
<thead>
<tr>
<th>Octave-band Center Frequencies (Hz)</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>STC Rating (Floor of IPEC)</td>
<td>37.0</td>
<td>45.0</td>
<td>54.0</td>
<td>60.0</td>
<td>65.0</td>
<td>47.0</td>
</tr>
</tbody>
</table>

### Transmission Losses (dB)

#### Octave-band Center Frequencies
- 125 Hz
- 250 Hz
- 500 Hz
- 1000 Hz
- 2000 Hz
- 4000 Hz

<table>
<thead>
<tr>
<th>Material</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>128</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ridged Insulation (3in.)</td>
<td>346</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Metal IPEC Bottom</td>
<td>128</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>IPEC</td>
<td>151.81</td>
<td>232.96</td>
<td>300.29</td>
<td>328.96</td>
<td>320.77</td>
<td>282.88</td>
</tr>
</tbody>
</table>

### Absorption Coefficients

**Total Absorption (sabins):** $a = \sum S\alpha$

**Surface Area (Sq. ft.):**

- Under IPEC Zone 2

<table>
<thead>
<tr>
<th>Surface Area Between Spaces (sq. ft.)</th>
<th>125 Hz</th>
<th>155 Hz</th>
<th>195 Hz</th>
<th>240 Hz</th>
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</thead>
<tbody>
<tr>
<td>Noise Reduction of Noise Coming from IPEC</td>
<td>37</td>
<td>47</td>
<td>57</td>
<td>68</td>
</tr>
<tr>
<td>Sound Pressure in IPEC</td>
<td>86</td>
<td>85</td>
<td>84</td>
<td>83</td>
</tr>
<tr>
<td>Sound Pressure in Zone 2 From IPEC Space</td>
<td>49</td>
<td>38</td>
<td>27</td>
<td>20</td>
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</tbody>
</table>

**Estimated Noise Level in Zone 2: 160 dB**
<table>
<thead>
<tr>
<th>Acoustical Breadth Calculations</th>
</tr>
</thead>
</table>

### Conference Room Acoustics

<table>
<thead>
<tr>
<th>Octave-band Center Frequencies</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8'' reinforced concrete slab</td>
<td>44.0</td>
<td>48.0</td>
<td>55.0</td>
<td>58.0</td>
<td>63.0</td>
<td>67.0</td>
</tr>
<tr>
<td>Transmission Losses (dB)</td>
<td>44.0</td>
<td>37.0</td>
<td>28.0</td>
<td>23.0</td>
<td>17.0</td>
<td>12.0</td>
</tr>
</tbody>
</table>

### Breakdown of Estimated Noise Levels by Zones

#### Noise Reduction of Noise Coming from Zone 1
- Sound Pressure in Zone 1: 44 dB
- Noise Reduction: 36 dB
- Estimated Sound Pressure Level in Staff Conference Space: 8 dB

#### Noise Reduction of Noise Coming from Zone 2
- Sound Pressure in Zone 2: 37 dB
- Noise Reduction: 3 dB
- Estimated Sound Pressure Level in Staff Conference Space: 34 dB

#### Noise Reduction of Noise Coming from Zone 3
- Sound Pressure in Zone 3: 28 dB
- Noise Reduction: 21 dB
- Estimated Sound Pressure Level in Staff Conference Space: 17 dB

#### Noise Reduction of Noise Coming from Zone 4
- Sound Pressure in Zone 4: 23 dB
- Noise Reduction: 14 dB
- Estimated Sound Pressure Level in Staff Conference Space: 9 dB

### Surface Area Between Zones

<table>
<thead>
<tr>
<th>Zone 1 and Zone 2</th>
<th>Surface Area (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>43</td>
</tr>
<tr>
<td>250</td>
<td>48</td>
</tr>
<tr>
<td>500</td>
<td>55</td>
</tr>
<tr>
<td>1000</td>
<td>65</td>
</tr>
<tr>
<td>2000</td>
<td>69</td>
</tr>
<tr>
<td>4000</td>
<td>73</td>
</tr>
</tbody>
</table>

### Total Absorption (sabins): a=∑ Sα

<table>
<thead>
<tr>
<th>Surface Area (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>2000</td>
</tr>
<tr>
<td>4000</td>
</tr>
</tbody>
</table>

### Estimated Sound Pressure Level in Staff Conference Space

<table>
<thead>
<tr>
<th>Room</th>
<th>Surface Area (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 and Zone 2</td>
<td>43</td>
</tr>
<tr>
<td>Zone 1 and Zone 3</td>
<td>47</td>
</tr>
<tr>
<td>Zone 1 and Zone 4</td>
<td>42</td>
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<tr>
<td>Zone 2 and Zone 3</td>
<td>52</td>
</tr>
<tr>
<td>Zone 2 and Zone 4</td>
<td>60</td>
</tr>
<tr>
<td>Zone 3 and Zone 4</td>
<td>63</td>
</tr>
<tr>
<td>Zone 1 and Staff Conference</td>
<td>44</td>
</tr>
<tr>
<td>Zone 2 and Staff Conference</td>
<td>37</td>
</tr>
<tr>
<td>Zone 3 and Staff Conference</td>
<td>28</td>
</tr>
<tr>
<td>Zone 4 and Staff Conference</td>
<td>23</td>
</tr>
</tbody>
</table>
### Equipment

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plumbing, equipment, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water meters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
<td></td>
</tr>
<tr>
<td>20-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
<td></td>
</tr>
<tr>
<td>30-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
<td></td>
</tr>
<tr>
<td>40-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
<td></td>
</tr>
<tr>
<td>50-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
<td></td>
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<tr>
<td>75-water supply</td>
<td>1</td>
<td>$4,193.60</td>
<td>$4,193.60</td>
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</tbody>
</table>

### Enclosure

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof, base, raised roof, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Sky Light, Skylight Sunroom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>1</td>
<td>$7,075.80</td>
<td>$7,075.80</td>
<td></td>
</tr>
</tbody>
</table>

### Penthouse Costs

- **Equipment Costs:**
  - Total: $30,863.60
- **Enclosure Costs:**
  - Total: $7,075.80
- **Total Penthouse Costs:**
  - Total: $37,939.40
### Penthouse Durations

Library In Metropolitan Washington, D.C.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Assembly Number</th>
<th>Description</th>
<th>Unit</th>
<th>Productivity (normal/day)</th>
<th>Crosses</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3050110901</td>
<td>Water, gas, ventilation, hot water, 1,600 lbs.</td>
<td>ea</td>
<td>0.3</td>
<td>3</td>
<td>4.4</td>
</tr>
<tr>
<td>2</td>
<td>3050115401</td>
<td>Unit, stainless steel, office and utilities, 65.080 lb.</td>
<td>ea</td>
<td>0.1</td>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td>2</td>
<td>3050116701</td>
<td>Pipe and other, mechanical, 21,000 lbs.</td>
<td>ea</td>
<td>0.4</td>
<td>1</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>3050301001</td>
<td>Pump, laser-cut, with water, 21,000 lbs.</td>
<td>ea</td>
<td>5</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>3050301601</td>
<td>Pump, laser-cut, with water, 21,000 lbs.</td>
<td>ea</td>
<td>7</td>
<td>1</td>
<td>0.5</td>
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<tr>
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<td>3050301601</td>
<td>Pump, laser-cut, with water, 21,000 lbs.</td>
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<td>1</td>
<td>0.7</td>
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<td>11</td>
<td>3050303101</td>
<td>Pump, laser-cut, with water, 21,000 lbs.</td>
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<tr>
<td>2</td>
<td>3050301001</td>
<td>Equipment, stainless steel, 1,600 lbs.</td>
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<tr>
<td>1</td>
<td>3050401501</td>
<td>Roof and wall, mechanical, 7,600 lbs.</td>
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<td>0.3</td>
<td>4</td>
<td>7.4</td>
</tr>
<tr>
<td>2</td>
<td>3050420010</td>
<td>Roof and wall, mechanical, 7,600 lbs.</td>
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<td>1</td>
<td>0.6</td>
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<tr>
<td>1.33</td>
<td>3050411601</td>
<td>ARL, caging, control.</td>
<td>ea</td>
<td>0.3</td>
<td>4</td>
<td>4.4</td>
</tr>
<tr>
<td>1.11</td>
<td>3050411601</td>
<td>ARL, caging, control.</td>
<td>ea</td>
<td>0.3</td>
<td>4</td>
<td>4.4</td>
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### Enclosure

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Assembly Number</th>
<th>Description</th>
<th>Unit</th>
<th>Lack</th>
<th>Productivity (normal/day)</th>
<th>Crosses</th>
<th>Duration (days)</th>
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<tbody>
<tr>
<td>2450</td>
<td>850101204500</td>
<td>Steel Joint Roof</td>
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<td>2450</td>
<td>800101206500</td>
<td>Single Ply 60 mil.</td>
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<tr>
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<td>820101345000</td>
<td>Conformed 32 Ga. Galvanized Steel, with Structural Steel Support, Colored</td>
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**Total Days:** 15.3