Presentation Outline

• Building Overview
• Analysis #1 – Natatorium Structural Redesign
• Analysis #2 – Mechanical System Modification
• Analysis #3 – Project Delivery Systems on Public Projects
• Analysis #4 – Glulam Connection Modification
• Conclusion and Recommendations
• Acknowledgments and Questions
Building Overview

- Located in Pearland, Texas; about 15 miles south of Houston, TX
- 105,000 SF

Building houses:
- Gymnasium
- Multi-Purpose Rooms
- Offices
- Classrooms
- Weight Room
- Locker Rooms
- Aerobics Room
- (1) 25-yard X 50-meter Competition Pool
- (1) 4 Lane X 25-yard instructional pool
Building Overview

- Construction began in May 2009 and is scheduled for completion in June 2010
- Design-Bid-Build delivery method
- Competitive bid/lump sum contract with general contractor
- $17 million project (Contract with general contractor)
Building Overview

Structural System:
- Steel in Recreation Center and Glulam in the Natatorium

Mechanical System:
- Chillers (2 Air-Cooled) and Air Handling Units (12) with VAV boxes

Electrical System:
- 3000 A Source, 29 Surface Mounted Panel Boards (15-408/277V and 14-208/120V), emergency generator

Fire Protection System:
- Wet pipe pre-action fire sprinkler system
Analysis #1 – Structural System

Structural - Breadth Topic #1

Problem:
The glulam structural system in the natatorium is very expensive.

Goal:
Identify an economical alternative structural system in the natatorium that will be of the same quality as the current glulam system.
Analysis #1 – Structural System

Structural - Breadth Topic #1

Alternative Structural System Comparisons:

Steel
- Cheapest
- Paint on steel can chip, particularly on accessible columns, causing steel corrosion.

Steel Joists and Concrete Columns – Selected System!
- Less Corrosive
- Concrete columns would not corrode
- Paint on steel joists would not chip since they are not easily accessible.

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Analysis #1 – Structural System
Structural - Breadth Topic #1

System Redesign:

- Using 2003 IBC Code:

<table>
<thead>
<tr>
<th>Type of Load</th>
<th>Design Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>20 lb/SF</td>
</tr>
<tr>
<td>Dead Weight</td>
<td>20 lb/SF</td>
</tr>
<tr>
<td>Wind</td>
<td>120 mph for 30 sec gust – exposure C – importance factor of 1.15</td>
</tr>
</tbody>
</table>

Design*:

<table>
<thead>
<tr>
<th>Member</th>
<th>Quantity</th>
<th>Size</th>
<th>Spacing/Reinforcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Columns</td>
<td>28</td>
<td>10&quot; X 10&quot;</td>
<td>25' on center/4-#5s</td>
</tr>
<tr>
<td>Steel Joists</td>
<td>468</td>
<td>25' - 14k1</td>
<td>4' on center</td>
</tr>
<tr>
<td>Steel Beams</td>
<td>14</td>
<td>106'- 104SLH22</td>
<td>25' on center</td>
</tr>
</tbody>
</table>

*Sized using the Steel Joist Institute Handbook and Concrete Reinforcing Steel Institute Manual
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Analysis #1 – Structural System
Structural - Breadth Topic #1

Cost:

<table>
<thead>
<tr>
<th>System</th>
<th>Glulam</th>
<th>Concrete and Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-Designed System</td>
<td>$1,070,000</td>
<td>$469,738</td>
</tr>
<tr>
<td>Proposed System</td>
<td>$469,738</td>
<td>$469,738</td>
</tr>
<tr>
<td>Savings with Proposed</td>
<td>$600,262</td>
<td>$600,262</td>
</tr>
</tbody>
</table>

System Cost Comparison

<table>
<thead>
<tr>
<th>System</th>
<th>Glulam</th>
<th>Concrete and Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Glulam</td>
<td>$1,070,000</td>
<td>$469,738</td>
</tr>
<tr>
<td>Concrete Columns</td>
<td>$20,380</td>
<td>$20,380</td>
</tr>
<tr>
<td>Steel Beams</td>
<td>$256,620</td>
<td>$256,620</td>
</tr>
<tr>
<td>Steel Joists</td>
<td>$182,650</td>
<td>$182,650</td>
</tr>
<tr>
<td>Metal Decking</td>
<td>$507,848</td>
<td>$507,848</td>
</tr>
<tr>
<td>Additional connections</td>
<td>$30,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>Total</td>
<td>$1,070,000</td>
<td>$1,070,000</td>
</tr>
</tbody>
</table>
Analysis #1 – Structural System
Structural - Breadth Topic #1

Recommendation: Replace the glulam structural system in the natatorium with a concrete and steel system

- Save over $600,000
- Eliminate problematic connection
- Maintain durability
- No change to construction duration
Analysis #2 – Mechanical System Modification

Problem:
Owner was persuaded to use (2) air-cooled chillers instead of a water-cooled chiller and cooling tower mechanical system.

Goal:
Determine if a water-cooled chiller and cooling tower system should have been used instead of an air-cooled chiller system.
Mechanical System Modification

Design Criteria:

Chiller:
- Capacity: 276 Tons
- Entering Water Temperature: 56°F
- Leaving Water Temperature: 42°F
- Flow Rate: 240 GPM

Cooling Tower:
- Leaving Water Temperature: 95°F
- Entering Water Temperature: 85°F
- Flow Rate: 3 GPM/Ton = 828 GPM

General:
- Dry Bulb Temp: 92°F
- Wet Bulb Temp: 77°F
Analysis #2 – Mechanical System Modification

# Mechanical System

## Case Study

**Pearland Recreation Center and Natatorium**

Matt Smiddy – AE CM Option

Senior Thesis Presentation

- **Building Overview**
- **Analysis #1 – Natatorium Structural Redesign**
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- **Conclusion and Recommendations**
- **Acknowledgments and Questions**

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### Cost Analysis: Pearland Recreation Center and Natatorium

#### New System Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing Tower - Material</td>
<td>$30,171</td>
<td>Designate Systems</td>
</tr>
<tr>
<td>Casing Tower - Labor</td>
<td>$2,610</td>
<td>RS Means</td>
</tr>
<tr>
<td>Additional Pumps &amp; Piping</td>
<td>$26,082</td>
<td>RS Means</td>
</tr>
<tr>
<td>Water-Cooled Chiller</td>
<td>$91,849</td>
<td>Trane</td>
</tr>
<tr>
<td>Water-Cooled Chiller (Labor &amp; Material)</td>
<td>$11,700</td>
<td>RS Means</td>
</tr>
<tr>
<td>Additional Structural Support for Casing</td>
<td>$10,557</td>
<td>Estimate from Southland</td>
</tr>
<tr>
<td>Towers (Labor &amp; Material)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost for Proposed System (Labor &amp; Material)</td>
<td>$180,000</td>
<td></td>
</tr>
</tbody>
</table>

#### Old System Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old System Cost</td>
<td>$228,523</td>
</tr>
</tbody>
</table>

**Systems Cost Comparison**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed System Cost</td>
<td>$180,000</td>
</tr>
<tr>
<td>Proposed System Cost (Labor &amp; Material)</td>
<td>$180,000</td>
</tr>
</tbody>
</table>

**Construction Cost Savings with Proposed System**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost Savings with Proposed System</td>
<td>$48,523</td>
</tr>
</tbody>
</table>

---
Analysis #2 – Mechanical System

Mechanical – Breadth Topic #2

Energy Costs:

Old System – (2) Air Cooled Chillers at 1.3 KW/Ton each
Energy Usage = 2 X 1.3 KW/Ton X 138 Tons = 358 KW

New System – (1) Water Cooled Chiller at 0.667 KW/Ton
(1) Cooling Tower at 0.879 KW/Ton
Chiller Energy Usage = 0.667 KW/Ton X 276 Tons = 184 KW
Cooling Tower Energy Usage = 0.879 KW/Ton X 276 Tons = 243 KW
Total Energy Usage = 427 KW

Total Additional Energy Costs** with Proposed System: 427 KW – 358 KW = 69 KW

Energy Added Costs**: 69 KW X 24 Hours X $0.1/KWHr = $165.6/Day Additional Cost

**This is assuming 100% load all day
Analysis #2 – Mechanical System
Mechanical – Breadth Topic #2

Payback Period:

• 293 days operating 24 hours/day at full load
• System would likely not be run at full load, much less all day
• Additional energy adjustments required
Analysis #2 – Mechanical System
Mechanical – Breadth Topic #2

Recommendation: Selection of an ideal system would require additional research on energy costs.

- Save $48,523 in construction costs
- Increase energy costs
- Have no effect on the duration of construction
- Additional construction considerations
Analysis #3 – Project Delivery
MAE Focus Topic

Problem:
Design-Bid-Build delivery methods frequently result in adversarial relationships between project team members.

Goal:
Determine when it is best to use a Design-Bid-Build delivery method.
Analysis #3 – Project Delivery
MAE Focus Topic

Analysis Process:
- Issued questionnaires
- Interviewed select team members
- Interviewed project team members from similar projects using different delivery methods.
Analysis #3 – Project Delivery
MAE Focus Topic

Project Comparison:
Recreation Center and Natatorium (DBB):
- Financial risk – Pro
- Better Design – Pro
- Cost and Schedule were managed – Pro
- Long Construction Duration – Con

In Summary: Quality, on budget project with longer construction duration.

Public Safety Building (DB):
- Owner bears financial responsibility – Con
- Design falls behind – Con
- Short construction duration - Pro

In Summary: A quickly constructed building, lacking in quality and resulting in cost overruns.

Project Team:

[Diagram showing project team and activities]
Analysis #3 – Project Delivery
MAE Focus Topic

Recommendation: Use a Design-Bid-Build delivery method for public projects!

- For a public project the owner’s number one priority is to be a good steward of taxpayer’s monies.
- DBB efficiently allocates financial risk away from the owner.
Analysis #3 – Project Delivery

MAE Focus Topic

MAE Course Applications:

AE 572 – Project Development and Delivery Planning:
• Delivery Methods
• Contracting Methods

AE 597I – CII Best Practices
• Pre-project planning
• Change Management
• Equitable Risk Allocation

CE 531 – Legal Aspects of Engineering and Construction
• Risk Allocation
• Contract Interpretation

Project Team:

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Analysis #4 – Glulam Connection

Problem:
A bolted connection between the glulam columns and the concrete footers in the natatorium proved difficult during erection.

Goal:
Determine the feasibility of using a welded connection in place of a bolted connection between the glulam columns and concrete footers in the natatorium.
Analysis #4 – Glulam Connection

Design Analysis:

Steel contact area with [12] 1” diameter anchor bolts:

\[ 12 \times 3.14 \times (0.5)^2 = 9.42 \text{in}^2 \]

Quantity of 1/8” weld required to obtain equivalent strength:

\[ \frac{9.42 \text{in}^2}{(1/8”)} = 75.36” \text{ of } 1/8” \text{ weld} \]
Analysis #4 – Glulam Connection

Cost Analysis:
The costs associated with using a welded connection are equivalent to the cost of a bolted connection.

Schedule Analysis:
Assuming 60" of 1/8" weld can be performed per hour, each connection would take 1.25 hours and with 28 connections a total of 35 man-hours of welding would be added. This addition is small enough that it can be neglected.
Analysis #4 – Glulam Connection

Recommendation: Use a welded connection in place of a bolted connection.

- Have no effect on construction cost
- Not change the construction duration
- Simplify erection of the glulam columns
Conclusions and Recommendations

Analysis #1 – Structural Modification:
Use a Concrete & Steel System
- $600,000 cost savings
- No change in durability
- No change in construction duration

Analysis #2 – Mechanical Modification
More research on energy costs required to determine ideal system
- $48,500 construction cost savings
- No change in construction duration
- Higher energy costs
Conclusions and Recommendations

Analysis #3 – Project Delivery Method

*Use Design-Bid-Build delivery method for public projects*
- Owner wants to avoid financial risk on public projects
- Design-Bid-Build efficiently allocates risk away from owners

Analysis #4 – Glulam Column Connection

*Use a welded connection instead of a bolted connection*
- Easier to construct
- No effect on cost
- No change in construction duration
Acknowledgments and Questions

Questions?

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City of Pearland:
Andrew Brinkley
Skipper Jones

Penn State OPP:
John Bechtel
Chris Musser

PSU AE Department:
Jim Faust
Chris Magent
Moses Ling
Kevin Parfitt
Robert Holland
David Riley