Farquhar Park Aquatic Center

York, PA

Jason Kukorlo
Structural Option
Faculty Consultant: Dr. Linda Hanagan
AE Senior Thesis Spring 2010

Presentation Outline

- Introduction
- Existing Structure
- Project Goals
- Structural Depth Study
  - Gravity System
  - Lateral System
- Architectural Breadth Study
- Building Enclosure Study
- Conclusions
- Questions

OUTLINE

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INTRODUCTION

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Building Statistics

- Natatorium Complex
- Location: York, PA
- Occupant: YMCA of York and York County
- Occupancy Type: Assembly
- Size: 37,000 SF
- Height: 53’-0”
- Not Constructed
- Cost: $13 Million (Estimate)
- Structural Engineer: Nutec Design Associates, Inc.

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Architecture

- Curved Roof
- Large Glazed Curtain Walls
- Precast Concrete Panels
- Metal Wall Panels
- Standing Seam Metal Roof
- Façade Plant Climbing System

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EXISTING STRUCTURE

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Gravity System

- Triangular Curved Steel HSS Trusses
  - Span 130'-0"
  - Spaced 30'-0" o.c.
  - Tapered Columns
- Steel HSS Columns
- Steel HSS Lobby Roof Trusses
  - Span 41'-0"
  - Spaced 15'-0" o.c.
- 12" Precast Concrete Hollow Core Planks
- 12" CMU Interior Walls

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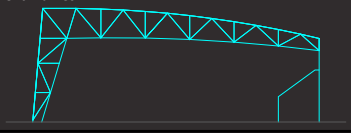
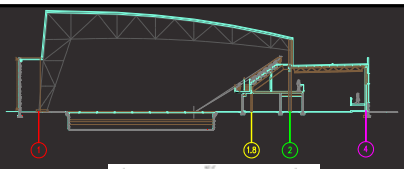
Lateral System

- North/South Direction:
  - Steel Braced Frames
  - Steel Moment Frames
- East/West Direction:
  - Steel Moment Frames





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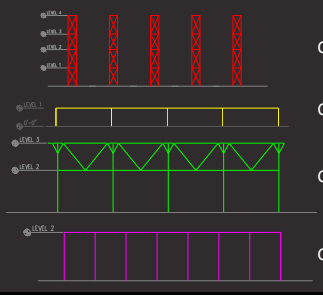
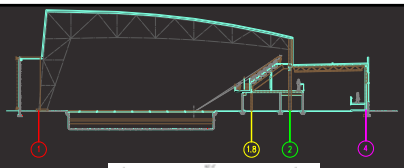


Column Line 1

Column Line 1.8

Column Line 2

Column Line 4



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PROJECT GOALS

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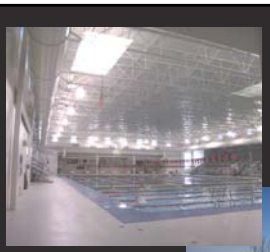
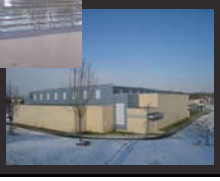
Problem

- Original project over budget

Goals

- Create alternate design to better meet financial needs of owner (YMCA)
- Maintain architectural integrity of original design





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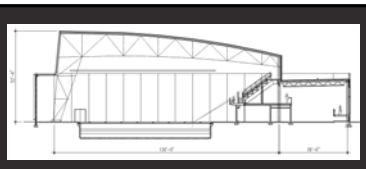
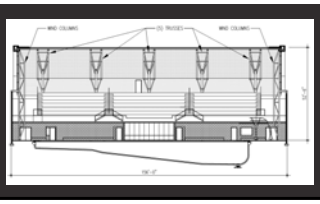
Solution

- Gravity System Design
  - King Post Truss System
  - Space Frame
  - Wood Truss System
- Lateral System Design
  - Concrete Moment Frames
  - Additional Perimeter Braced Frames





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STRUCTURAL DEPTH

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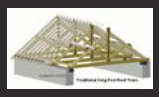
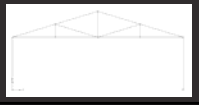
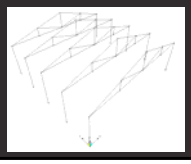
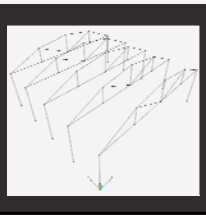
Steel King Post Truss System

- Final Design:
  - 20’-0” Depth
  - 30’-0” Spacing to Match Existing
  - 130’-0” Span
- More Cost Effective
- Too Simple
- Lacked Architectural Freedom









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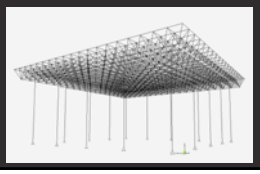
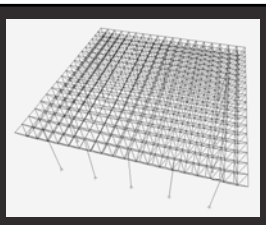
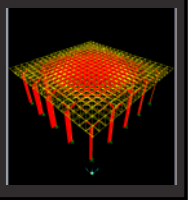
Steel Space Frame

- Investigated 4', 8', and 12' Modules
- Various Depths
- Final Design: 8'-0" Modules with 8'-0" Depth
- Too Costly due to Number of Joints







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Wood Truss System

- Glulam most appropriate for 130'-0" span
  - Southern Pine Glulam I.D. #50
  - Pressure treatment
- 10 PSF applied to bottom chord for speakers
- Decreased spacing required
  - 15'-0", 10'-0", 8'-0"
- Column relocations
- SAP2000
  - Distributed loads applied to top and bottom chord

Loads Applied to Top Chord of Glulam Trusses	
DEAD	**PSF**
Zinc Standing Seam Metal Roof Panels	1.5
1/2" Moisture Resistant Gypsum Board	2.5
4 1/2" Rigid Insulation	6.75
3" Decking	7.6
Superimposed	5
Assumed Self Weight	5
Total	28.35
Use	**30**
LIVE	
L_r	**20**
SNOW	
S	**23.1**

- 2005 National Design Specification for Wood Construction
- Controlling Load Combination: $D + L_r$
  - Live: $C_D = 1.0$
  - Snow: $C_D = 1.15$
- Wet Service Factor

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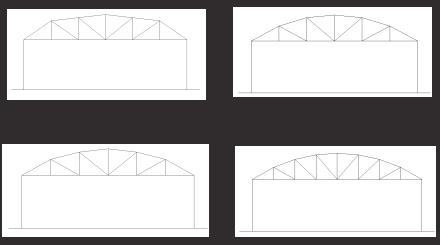
Wood Truss System



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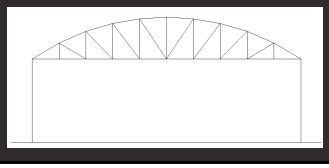
Wood Truss System

- Final Design:
  - 20'-0" Depth
  - 130'-0" Span
  - 8'-0" Spacing

SUMMARY	
Top Chord	6 3/4" x 12 3/8"
Bottom Chord	6 3/4" x 8 1/4"
Web Members	6 3/4" x 6 7/8"
West Column	6 3/4" x 15 1/8"
All members are Southern Pine, Glulam I.D. #50	



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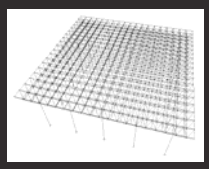
Comparison

Comparison of Three Alternate Roof Systems			
	Cost	Feasibility	Architectural Impact
Steel King Post Trusses	Competitive	High	Poor
Steel Space Frame	High	Poor/Moderate	Poor/Moderate
Glulam Trusses	Competitive	High	High

King Post Truss System



Space Frame

Glulam Truss System

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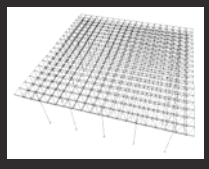
Final Selection: GLULAM TRUSS SYSTEM

King Post Truss System



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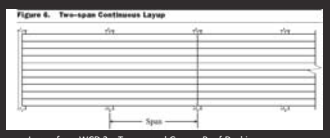
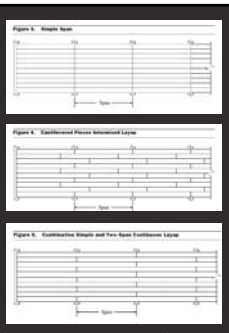
Decking

- Laminated Decking
  - Southern Pine
- Load Tables: Timber Construction Manual
- 3" Nominal Thickness Required
  - Actual Size: 2 ¼" x 5 3/8"



- Image from WCD 2 – Tongue and Groove Roof Decking



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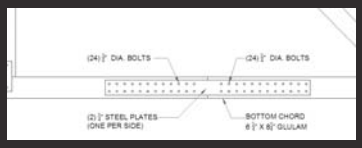
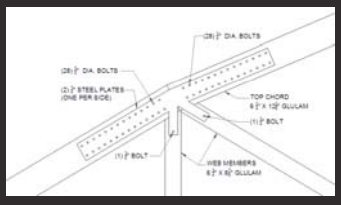
Glulam Truss Connections

- Bolted Steel Side Plates
  - Constant width of truss members (6 ¾")
- Large Connections (F ≅ 50,000 lb)
- Considered Shear Plates



Typical Bottom Chord Splice Connection

- 2005 National Design Specification for Wood Construction



Typical Top Chord Connection

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Wind Loads

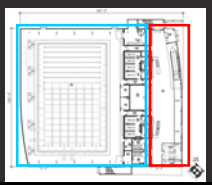
- Recalculated to account for new building shape and increased height (60'-0")

Seismic Loads

- Recalculated to account for increased building weight
  - Heavier roof system
  - Concrete moment frames

Distribution of Loads

- Flexible Diaphragm (Wood Roof System)
  - Based on tributary areas
- Rigid Diaphragm (Lobby Roof Trusses)
  - Based on relative stiffness



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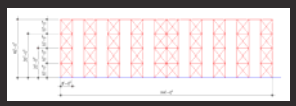
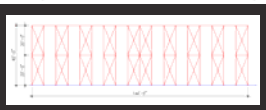
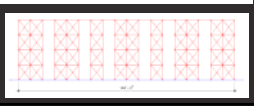
Wood Braced Frame Column Line 1

- To replace original steel braced frame
- Various configurations
  - Architectural considerations
- Brace each glulam column
- Controlling Load Combination: D + 0.75W + 0.75S
  - Torsional effects included
- SAP2000

Other Possible Configurations







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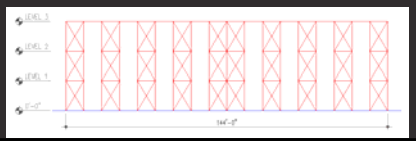
Wood Braced Frame Column Line 1

- Final Design:
  - 10 Separate Braced Frames
  - 3 X-Braces Vertically per Frame
  - Member Size: 3 ½" x 6 7/8" Southern Pine Glulam



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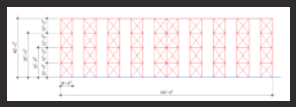

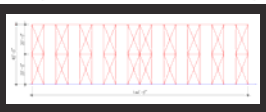

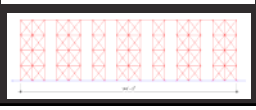

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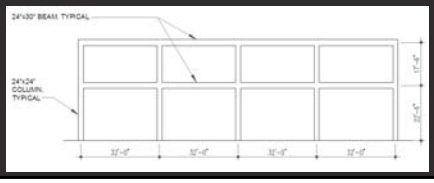
Concrete Moment Frame Column Line 2

- Load patterns
- Columns: 24"x24" w/ (12) #8



- ACI 318-08
- PCA Column
- SAP2000

- Increased column spacing

- Beams: 24"x30"
  - Negative-Moment Reinf: (10) #7
  - Positive-Moment Reinf: (8) #6

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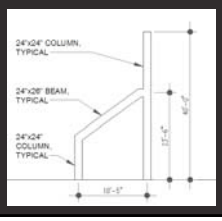
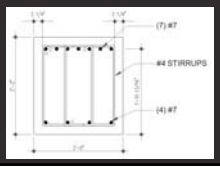
Concrete Moment Frame
East/West Direction

- Columns: 24”x24” w/ (12) #8



- ACI 318-08
- SAP2000

- Beams: 24”x26”
  - Negative-Moment Reinf: (7) #7
  - Positive-Moment Reinf: (4) #7



Typical Beam

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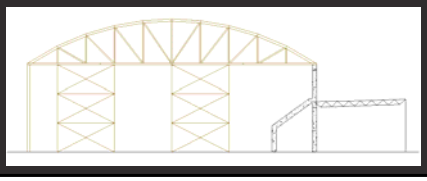
Wood Braced Frames
East/West Direction

- Typical Member Size: 6 ¾” x 6 7/8” Glulam
  - Southern Pine



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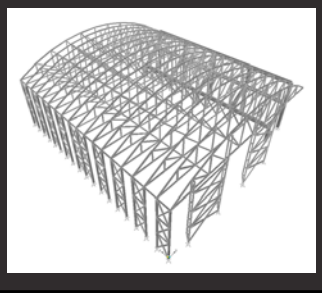
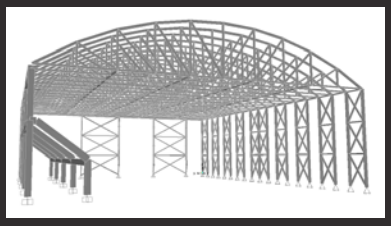
3D Models





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Cost Comparison

Estimated Cost Comparison	
	Cost ($)
Wood Roof System	
Metal Side Plates	14,212.00
Laminated Roof Deck	113,770.80
Plywood Sheathing	17,643.60
Glulam Trusses	242,011.14
High-Strength Bolts	148,845.24
TOTAL	**536,482.78**
Steel Roof System (Original Design)	
Galvanizing of Trusses	15,253.27
Galvanizing of Metal Roof Deck	35,773.92
Metal Roof Deck	369,298.80
Steel Trusses	250,208.90
TOTAL	**670,534.89**
Concrete Moment Frames	
Formwork for Beams	22,381.23
Formwork for Columns	11,938.20
Columns	39,951.08
Beams	77,852.52
Reinforcing for Beams	23,215.57
Reinforcing for Columns	9,056.67
TOTAL	**184,395.27**
Steel Moment Frames (Original Design)	
Beams	56,433.24
Columns	45,960.09
TOTAL	**102,393.33**

Total Overall Estimated Costs	
	Cost ($)
Alterntate Structural System	
TOTAL	**720,878.05**
Original Structural System	
TOTAL	**772,928.22**

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ARCHITECTURAL BREADTH

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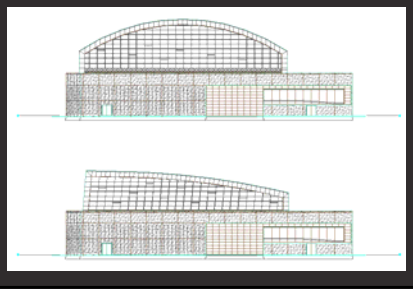
Roof Shape and Facade



- Increase in height
- Vertical mullions vs. slanted mullions
- Modification to curved roof shape

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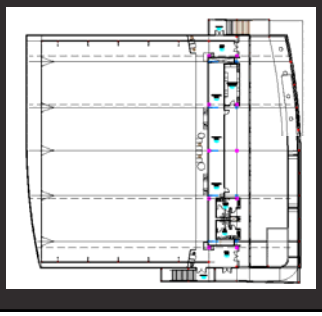
Room Layouts

- 10 Columns Changed Size
  - 8 columns were relocated
- Mechanical Openings

Ground Level

Concourse Level



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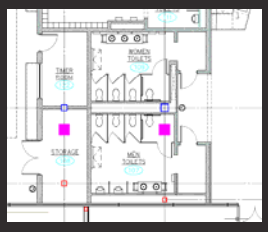
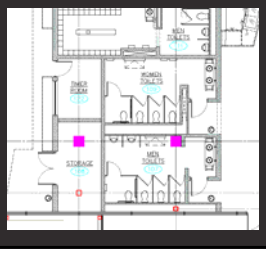
Room Layouts

New Columns with Original Room Layouts



Solution



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BUILDING ENCLOSURE BREADTH

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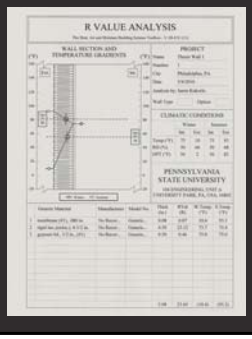
Moisture and Thermal Control

- H.A.M. Toolbox
  - Indoor Temp = 75°F to 85°F
  - Relative Humidity = 50% to 60%
  - Location of dew point in wall or roof system
  - Proper location of vapor barrier



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Moisture and Thermal Control

- DensDeck
  - Moisture-resistant roof board
  - Performs well when exposed to high humidity
  - Retains strength
- Precast Concrete Insulated Wall Panels
  - Used to enclose most of building
  - 8" thick
  - Condensation cannot form inside
  - Acoustical properties

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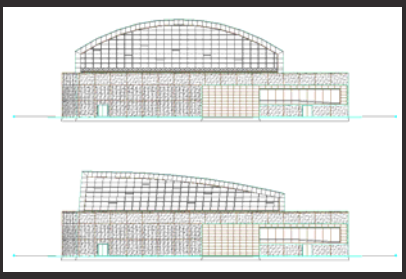
Glazing

- Solera-T Insulated Translucent Glazing Units
  - Large glass curtain walls enclosing indoor pool
  - Two lites of glass
  - High thermal performance insulating core
  - Admit diffuse light
  - Very strong
    - 48"x96" panel capable of supporting 500 PSF



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CONCLUSIONS

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Conclusions

- The glulam truss system provides a cost effective alternative design for the natatorium
- Architectural integrity maintained with curved roof
- Natatorium properly designed for thermal and moisture control

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Acknowledgements

- Nutec Design Associates, Inc.
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  - Professor Robert Holland
  - The entire AE faculty and staff

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QUESTIONS