SteelStacks
Performing Arts Center

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Spring Thesis 2013

Bethlehem, Pennsylvania

Performing Arts Center

- **Building Introduction**
- Problem Statement
- Proposed Solution
- Gravity Redesign
- Lateral Redesign
- Acoustics Analysis
- Architectural Impact Study
- Conclusions

Building Introduction

- Building Occupant: ArtsQuest
- 67,167 sq. ft.
- 4 stories, varying floor-to-floor heights
- Total Height: 64 ft above grade
- Construction: January 2010 - April 2011
- Design-Bid-Build
- Construction Cost: $21 million

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Project Team

- **Owner:** ArtsQuest
- **Architect:** Spillman Farmer Architects
- **Structural:** Barry Issett & Associates, Inc.
- **CM:** Alvin H. Butz, Inc.
- **Site/Civil Engineer:** French and Parrello

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Architectural Overview

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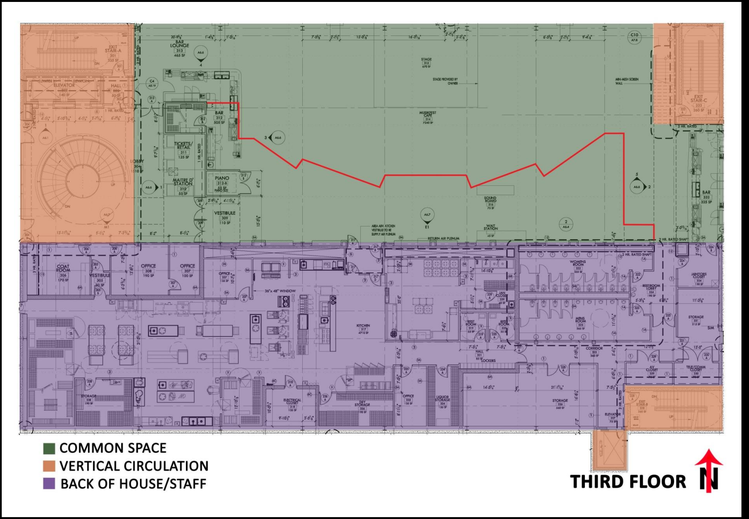
- Plans
- Glass curtain walls
- Exposed ceilings
- Large spans & cantilevers
- Atriums



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Existing Structural Overview

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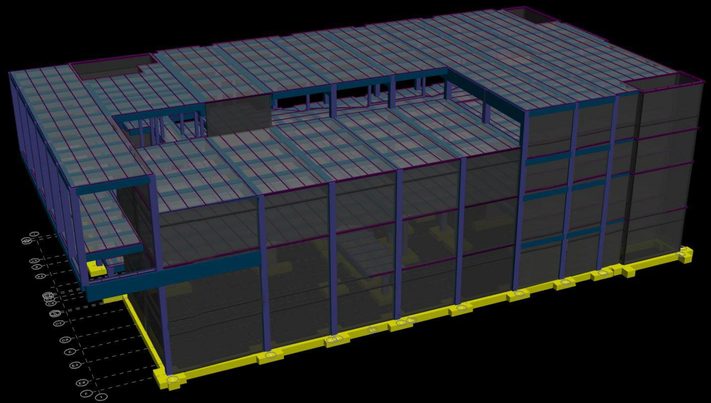
- Gravity System
  - Foundation
    - 3000 psf soil bearing pressure
    - 4” slab-on-grade
    - Square and strip footings
  - Floor System
- Lateral System



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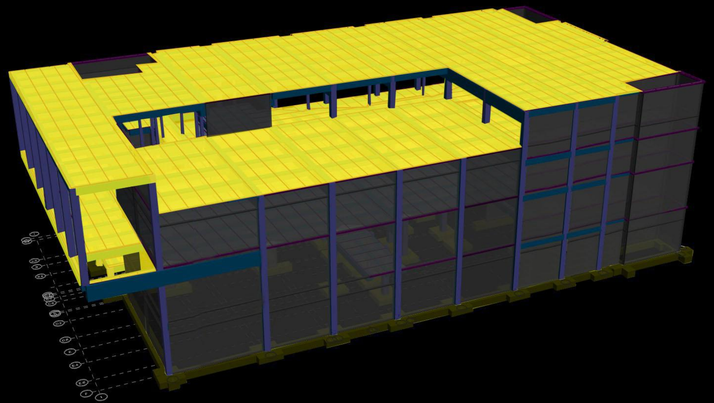
Existing Structural Overview

- Gravity System
  - Foundation
  - Floor System
    - 5-8” slabs on composite metal decking
      - f’c = 4000 psi
    - Columns & foundations
- Lateral System



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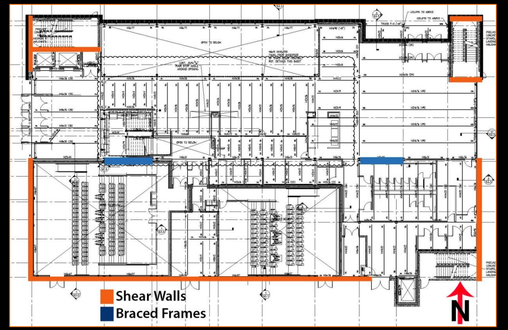
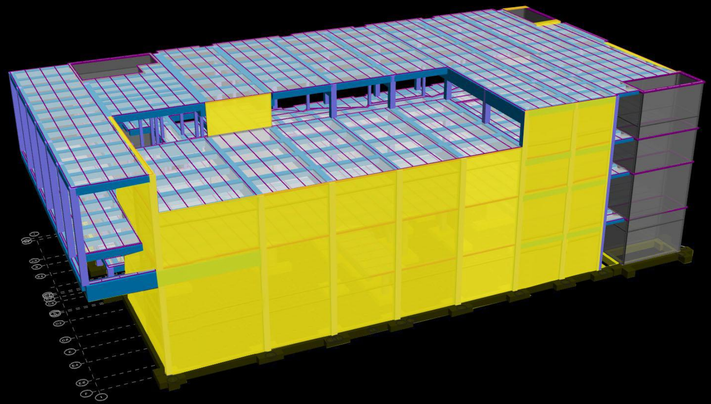
Existing Structural Overview

- Gravity System
  - Foundation
  - Floor System
- Lateral System
  - Dual system
  - Braced frames
  - Precast shear walls





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Problem Statement

- Scenario:
  - Redesign structural system in reinforced concrete
- Evaluate based on:
  - Structural performance
  - Acoustics
  - Aesthetics
  - Cost

Proposed Solution

Goals:

- Design controlling bay per floor
  - Comparing reinforced concrete to prestressed concrete
- Design controlling lateral system shear wall
- Confirm results via computer modeling software
- Consider impact on acoustics (Breadth I)
- Minimize impact on architecture (Breadth II)

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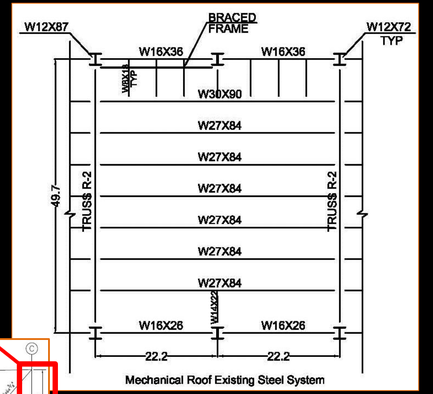
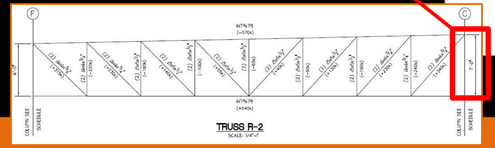
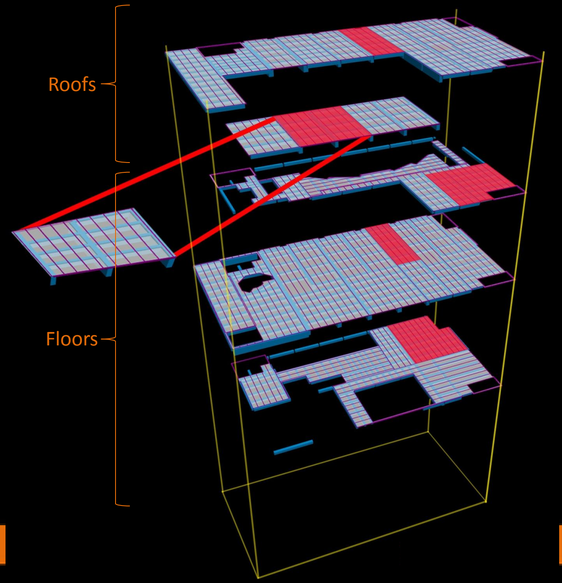
Gravity Redesign

- Areas of Concern
  - Long spans
  - Cantilevers
  - Floor-to-floor height
- Mechanical Roof
  - Existing depth 7’0”



Mechanical Roof Existing Steel System





CONTROLLING BAYS

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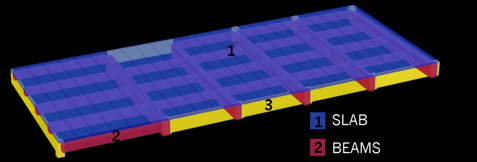
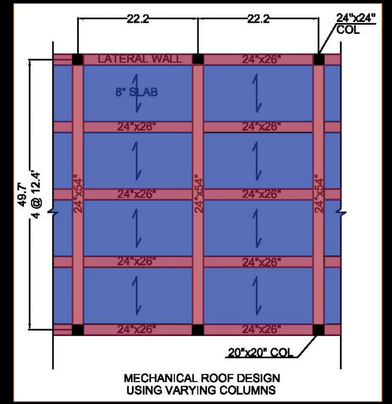
Gravity Redesign

- Mechanical Roof
  - Reinforced one-way
    - f'c = 4000 psi
  - Prestressed one-way
    - ADAPT-PT program use
  - Comparison
  - Columns
  - Cost



Gravity Design Results: Mechanical Roof			
Member	**Dimensions**	**Location**	**Reinforcement**
Slab	8"	Top/Bottom	#4s @ 8"
		Transverse	#4s @ 12"
Exterior Beam	26"x24"	Left Support	(4) #7s
		Midspan	(5) #6s
		Right Support	(4) #7s
Interior Beam	26"x24"	Left Support	(3) #9s
		Midspan	(3) #9s
		Right Support	(7) #10s
Girder	24"X54"	Left Support	(7) #10s
		Midspan	2 layers (8) #10s
		Right Support	(7) #10s



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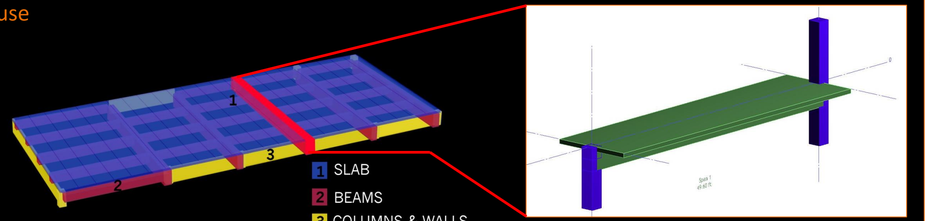
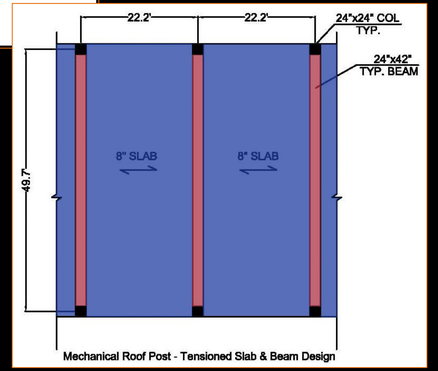
Gravity Redesign

- Mechanical Roof
  - Reinforced one-way
  - Prestressed one-way
    - f'c = 8000 psi
    - ADAPT-PT program use
  - Comparison
  - Columns
  - Cost

Prestrssed Gravity Design Results

Member	Dimensions	Location	Reinforcement	1/2" Ø Strands
Slab	8"	Top Upper	#7s @ 9"	@ 10" o.c.
		Top Lower		
		Bottom Upper	#4s @ 12"	
		Bottom Lower		
Beam	42"x24"	Top Upper	(9) #7s x 40'0"	(15)
		Top Lower	---	
		Bottom Upper	(2) #7s x 22'0"	
		Bottom Lower	(3) #7s x 50'0"	





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Gravity Redesign

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  - Reinforced one-way
  - Prestressed one-way
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	Design Considerations	Reinforced Concrete One-Way Slab and Beam	Prestressed One-Way Slab and Beam
Construction	Depth of Slab (in)	8	8
	Depth of System (ft)	4.6	**3.6**
	Cost ($/SF)	**17.96**	19.64
	Fire Rating (hr)	1	1
	Fire Protection	None	None
	Schedule	**Curing & formwork time required**	Slightly more lead time; more coordination required
	Constructability	**Moderate**	Difficult
Structural	Foundation	Approx same weight, no change in foundation considerations	
	Seismic Increase	Negligible Difference	
	Lateral	Negligible Difference	
Architectural	Impact	Floor-to-floor height better	**Floor-to-floor height better, elimination of some columns possible**
Serviceability	Deflection (in)	0.60	**0.32**
	Vibration Control	Satisfactory	Satisfactory

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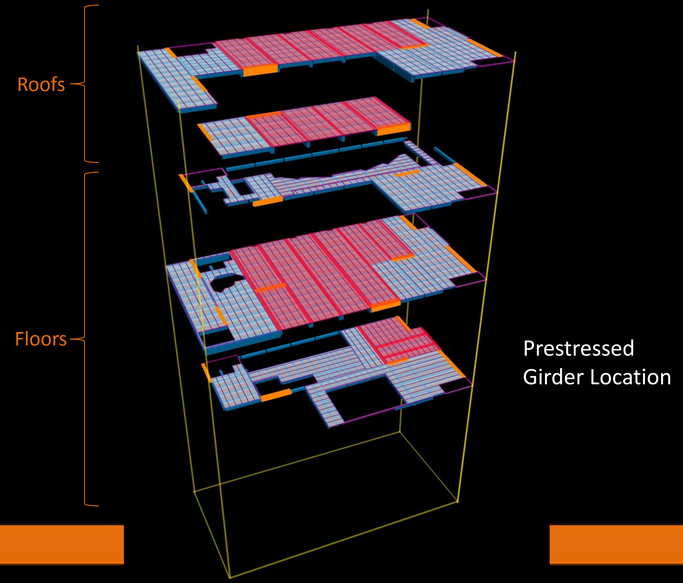
- Mechanical Roof
- Reinforced one-way
- Prestressed one-way
  - ADAPT-PT program use
- Comparison
- Columns
- Cost



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Gravity Redesign

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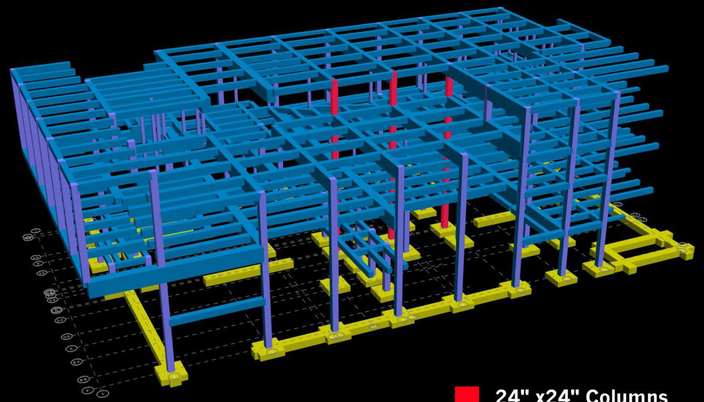
  - Prestressed one-way
    - ADAPT-PT program use
  - Comparison
  - Columns
  - Cost

Gravity Design Results: Mechanical Roof						
	Member	f'c (psi)	Dimensions	Location	Reinforcement
1	**A-8** (exterior)	4000	20"X20"	Longitudinal Transverse	(6) #9s #4s @ 12"
2	**C-7** (interior)	6000	24"X24"	Longitudinal Transverse	(16) #9s #4s @ 12"
3	**F8.8** (exterior)	4000	20"X20"	Longitudinal Transverse	(6) #9s #4s @ 12"
4	**E8.8** (interior)	4000	20"X20"	Longitudinal Transverse	(6) #9s #4s @ 12"



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Gravity Redesign

- Mechanical Roof
  - Reinforced one-way
  - Prestressed one-way
    - ADAPT-PT program use
  - Preliminary comparison
  - Columns
  - Cost

- Cost Comparison
  - Existing $17.93/sf
  - Reinforced one-way $17.96/sf
  - Prestressed one-way $19.64/sf

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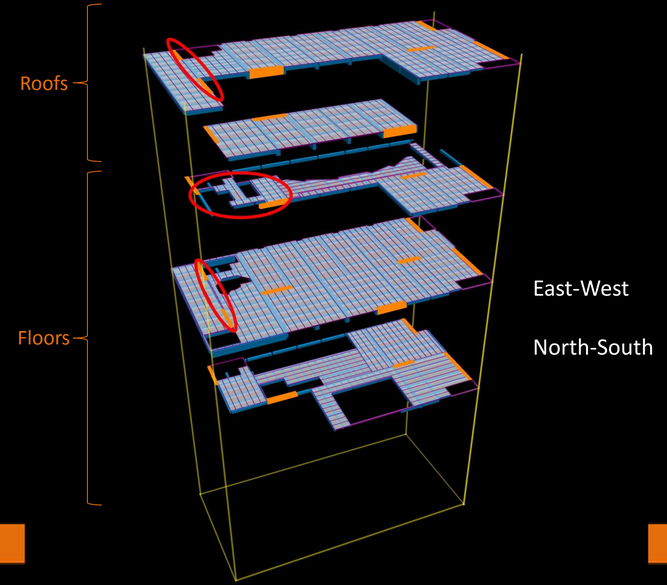
Lateral Redesign

- Load Path
- Focus Areas
  - Shear Walls
  - Torsional irregularity
  - Seismic loads



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Lateral Redesign

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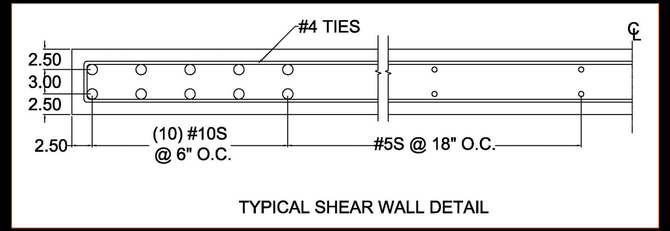
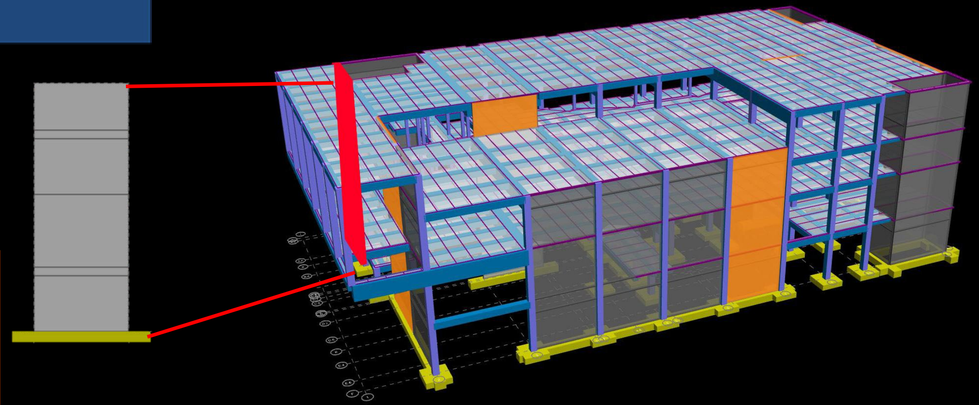
- Load Path
- Focus Areas
  - Shear Walls



TYPICAL SHEAR WALL DETAIL



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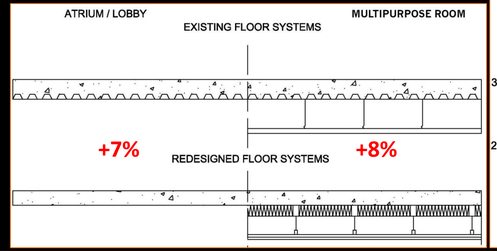
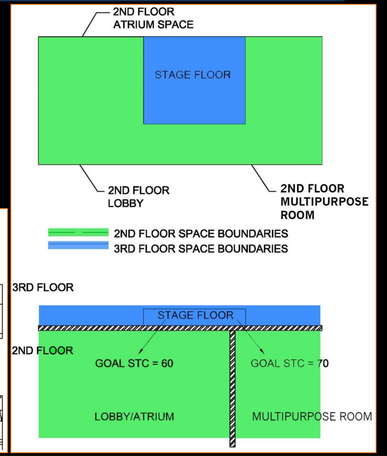
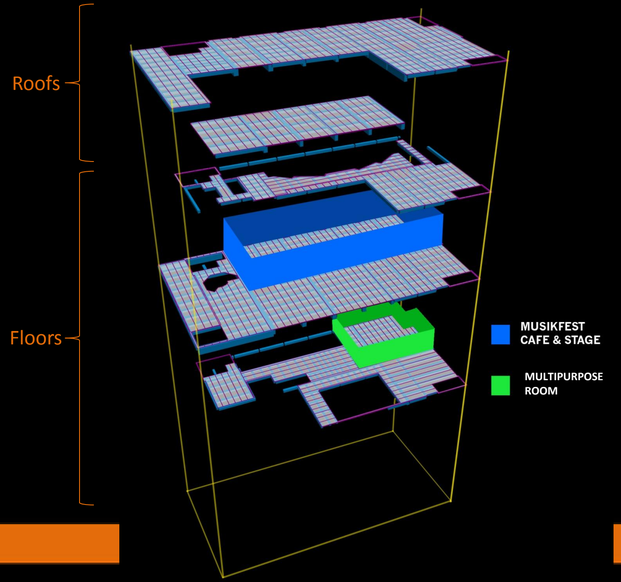
Acoustics Analysis

- Sound Transmission Criteria
- Reverberation Time
  - Spaces
  - Resulting design & cost







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Architectural Impact Study

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- Creative Commons
- Multipurpose Room
  - Space flow
  - Aesthetics
  - Design Impact

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Conclusions

- Redesign improves structural floor height
- Concrete is an efficient system for cantilevers and larger spans
- Diaphragm better integrated into use for lateral system & shear walls
- Better room acoustics & sound isolation
- Architectural spaces minimally impacted

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Acknowledgements

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Fellow classmates, family, and God

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Questions & Comments?

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