University of Central Florida's Academic Villages
Orlando, Florida

Samuel Avila
Structural Option
April 11, 2006

Advisor:
Dr. Thomas Boothby

Presentation Outline

Building Introduction

Problem/Proposal

Post-Tensioned One Way Slab

Shear Wall Analysis

Mechanical Analysis

Acoustical Analysis

Conclusions

Building Introduction

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Existing System

Problem

Proposal

Structural System Redesign

Breath work

Conclusions

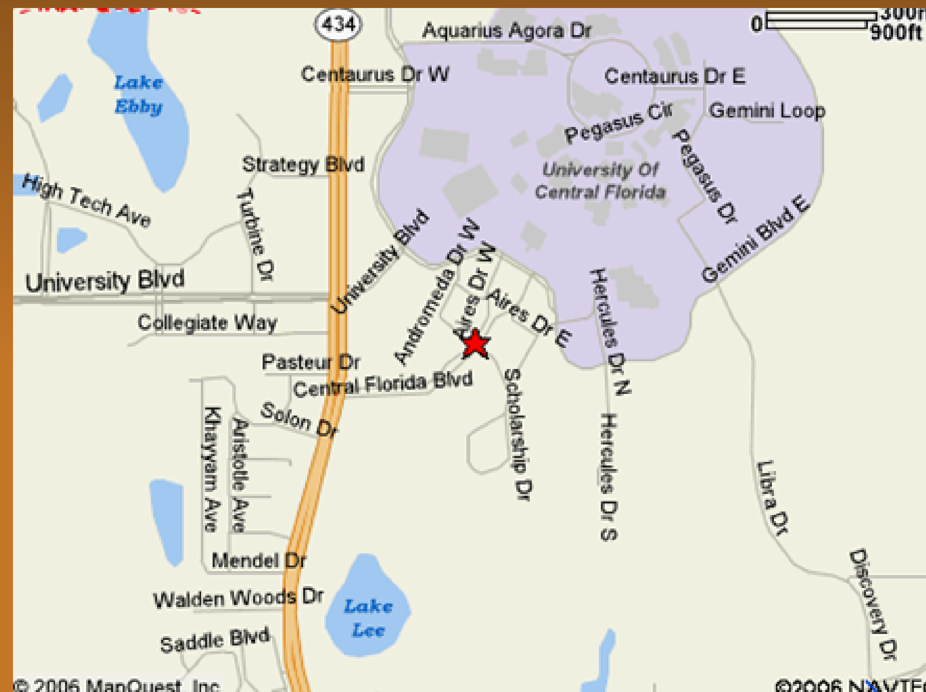
Location

Central Florida Blvd

Southwest of UCF's main campus.

Function

Student Housing



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Building Introduction

Nike Community

7 separate buildings

24'0" x 28'0" units

40-60 apartment units per building

Size

Varies: Footprints range from 14,000 sq ft. to 22,000 sq ft.

4 stories above grade

Cost

$63 million

Time Frame

Began: August 1999

Completed: July 2002

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Building that I chose to analyze

Building Introduction

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Primary Project Team	
Owner	University of Central Florida
Architect	Hanbury Evans Wright Vlattas
Structural Engineer	TLC Engineering
Geotechnical Engineer	Nodarse & Associates
Mechanical Engineer	TLC Engineering
Contractor	Centex Homes
Civil Engineer	Vanasse Hangen Brustlin, Inc.

Building Introduction

Design Codes
American Institute of Steel Construction (AISC)
Load and Resistance Factor Design (LRFD)
American Society for Testing and Materials (ASTM)
Specifications for Structural Concrete (ACI 301)
Specifications for Masonry Structures (ACI 530.1)
American With Disabilities Act (ADA)
Florida Accessibility Code

Design Live Loads	
Roof	20 psf
Corridors	80 psf
Mechanical Rooms	150 psf
Stairs, Public Areas, Lobby	100 psf
All Other Rooms	40 psf
Superimposed Dead Loads	
M/E/P	10 psf
Partitions	20 psf

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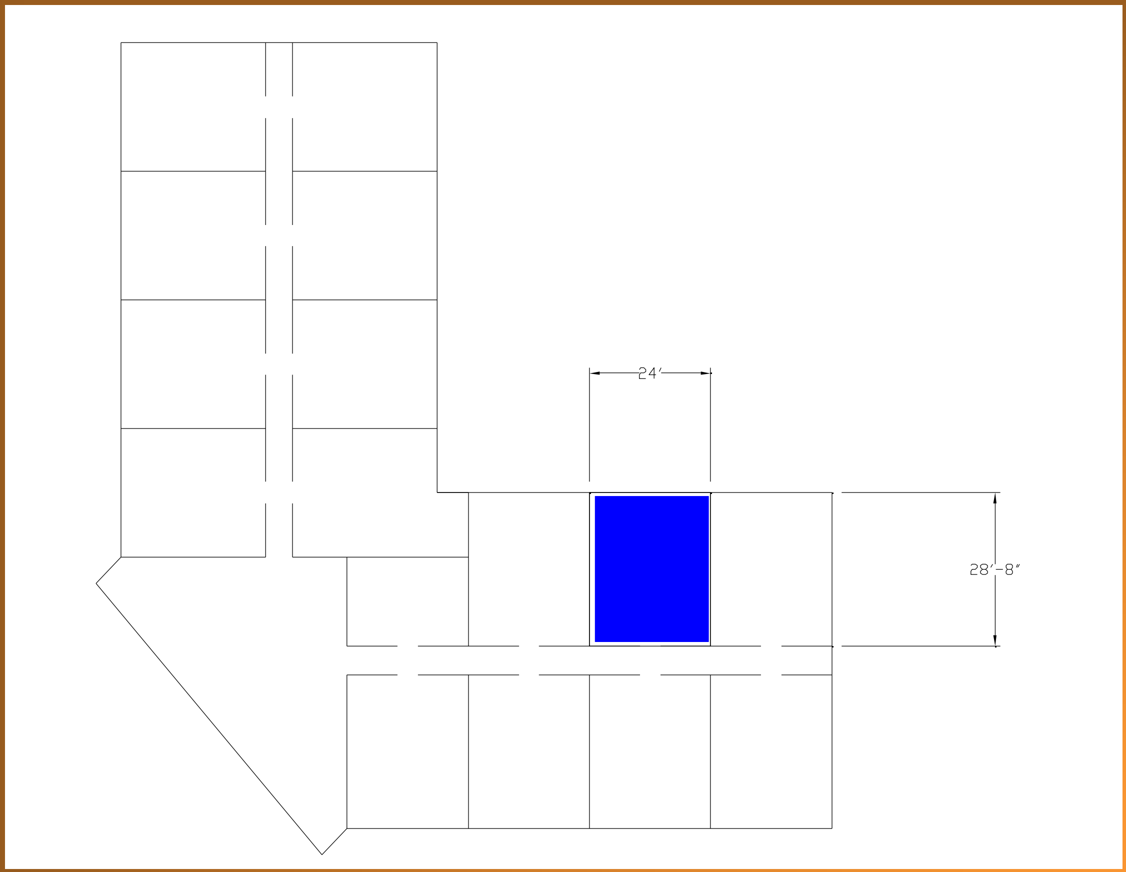
Building Introduction

Building Footprint



Gravity System

Infinity System

Epicore Metal Deck

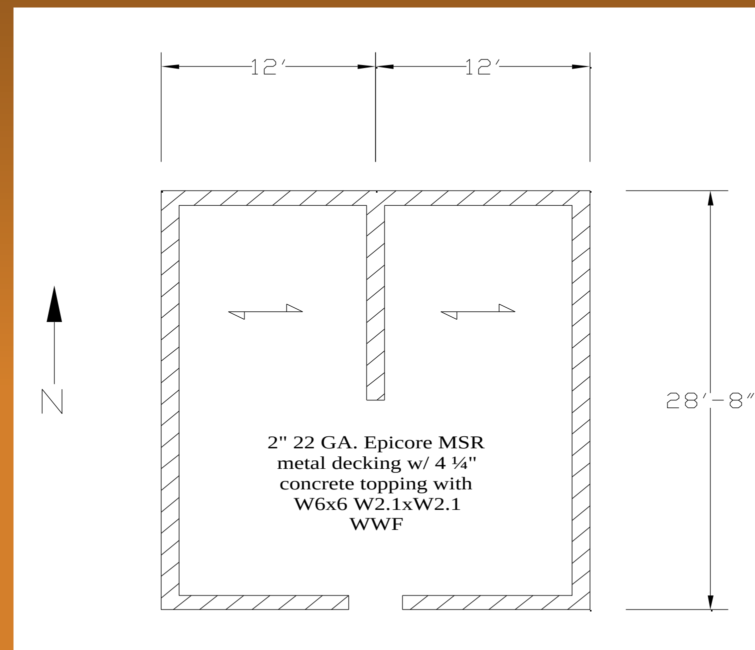
4 ½“ Concrete Slab

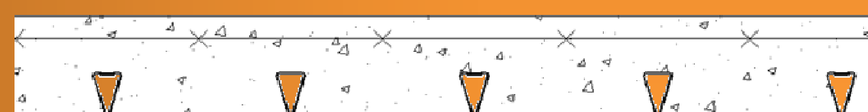
Welded Wire Reinforcement

Typical Span

Between 8” Masonry Bearing Walls

12’0” Span in East-West Direction





Building Introduction

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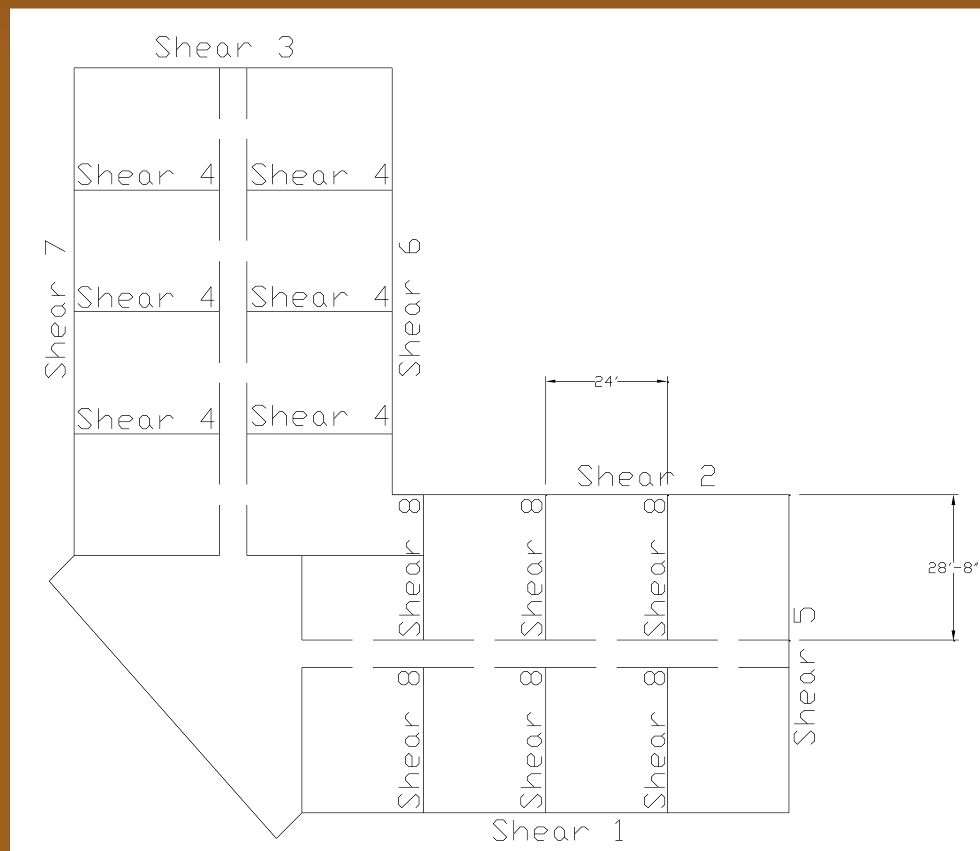
Lateral System



Building Introduction

Lateral System

Shear Wall Force Schedule (kips)								
	Shear 1		Shear 2		Shear 3		Shear 4	
	Each Floor	Total	Each Floor	Total	Each Floor	Total	Each Floor	Total
4th Floor	7.21	7.21	6.01	6.01	2.56	2.56	1.07	1.07
3rd Floor	13.52	20.73	11.27	17.28	4.79	7.35	1.97	3.04
2nd Floor	13.48	34.21	11.23	28.51	4.77	12.12	1.98	5.02
	Shear 5		Shear 6		Shear 7		Shear 8	
	Each Floor	Total	Each Floor	Total	Each Floor	Total	Each Floor	Total
4th Floor	2.1	2.1	6.04	6.04	5.18	5.18	1.07	1.07
3rd Floor	3.94	6.04	11.32	17.36	9.7	14.88	1.97	3.04
2nd Floor	3.93	9.97	11.28	28.64	9.67	24.55	1.98	5.02

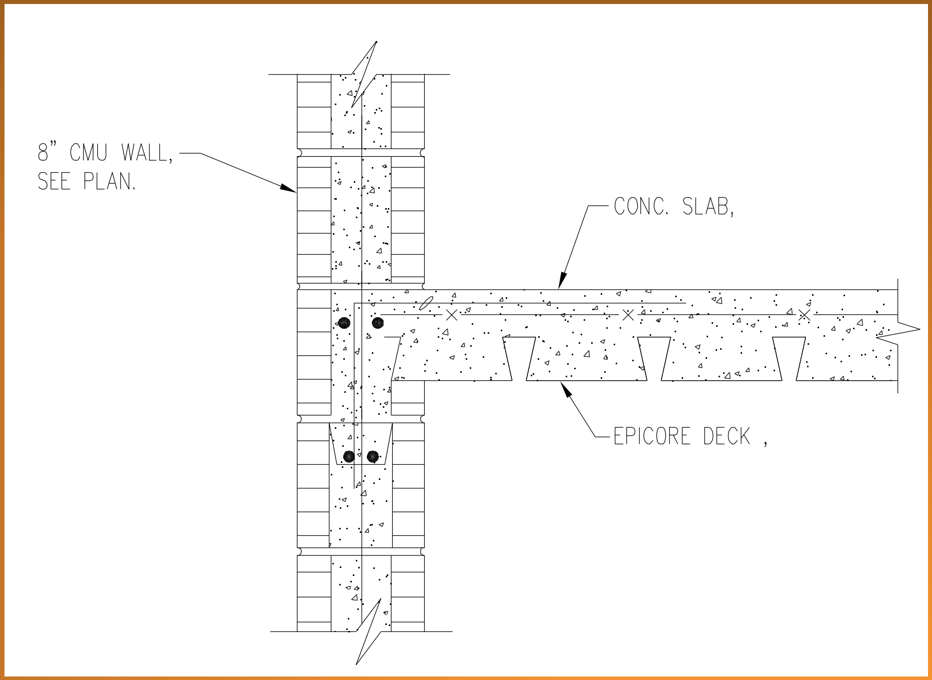
Building Introduction

Lateral System

Description

Interior and Exterior Masonry Shear Walls

All Walls 8” Masonry Blocks w/ Type S mortar and #5 @ 24” Reinforcement

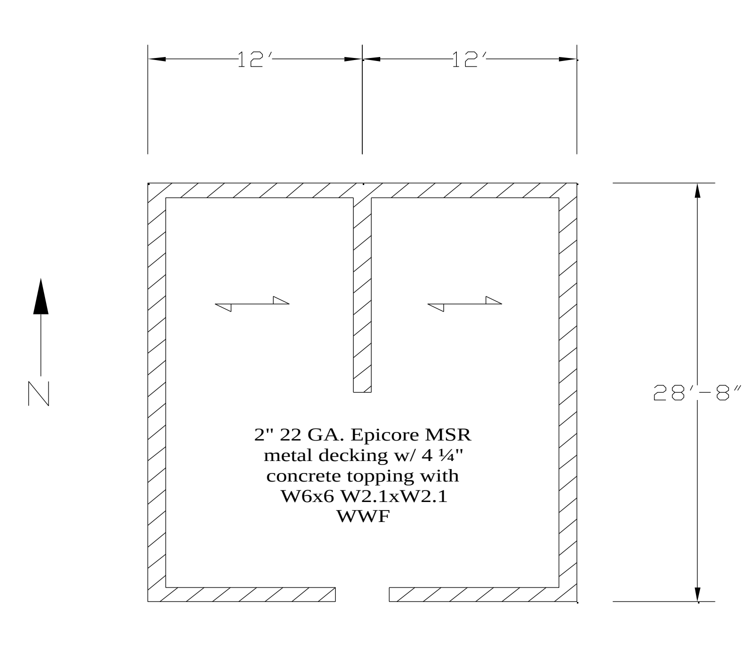


Problem/Proposal

Problem

Criteria à Layout Flexibility

Existing Floor System Limits the Span Length to 12'0"



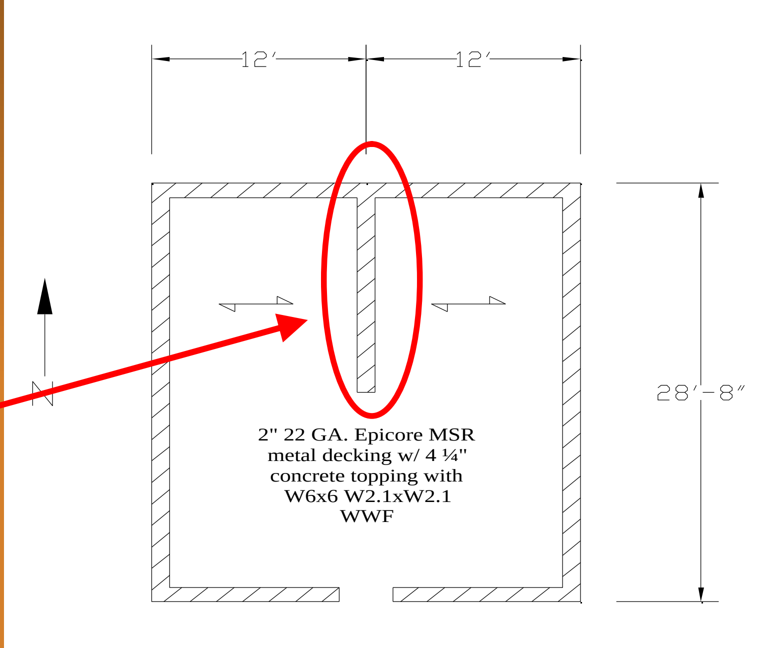
Problem/Proposal

Problem

Criteria à Layout Flexibility

Existing Floor System Limits the Span Length to 12'0"

Bearing Wall Included at Midspan Due to Existing Gravity System



Problem/Proposal

Structure System Investigation

Analyze Gravity System as a Post-Tensioned One-Way Slab System

Redesign Shear Walls For Additional Loads Due to New Floor System

Mechanical Breadth Study

Investigation to Determine if an Energy Recovery Ventilator (ERV) System is a Feasible Opportunity to Reduce HVAC Operational Costs

Acoustical Breadth Study

Investigation to Verify That the New Structure Meets IBC 2000 Requirements

Acoustics Check For Rooms Adjacent to Air Handling Units

Problem/Proposal

Design Goals (Structural)

Make Units More Flexible By Removing Interior Bearing Wall at Midspan in Each Unit

Minimize Slab Depth So That the Floor to Floor Height Remains Constant

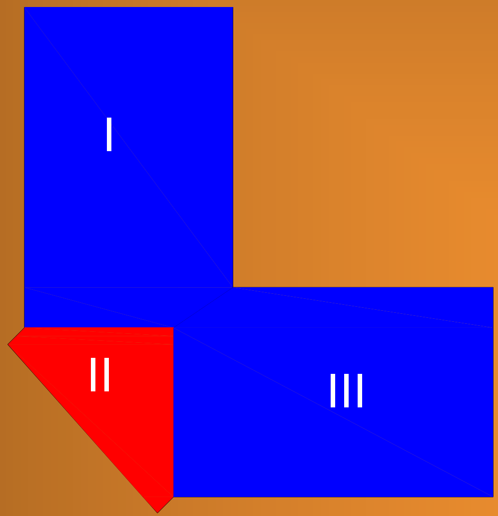
Design Goals (Mechanical/Acoustics)

Maintain or Improve the Quality of Life for All Residents

Post-Tensioned One-Way Slab

Four Case Investigations (ACI 318-02 18.3.3)

1. One-Way Simple Span Class U (uncracked)
2. One-Way Simple Span Class T (transition)
3. One-Way Continuous Span Class U (uncracked)
4. One-Way Continuous Span Class T (transition)



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Post-Tensioned One-Way Slab

Flexure/Deflection

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- Existing System
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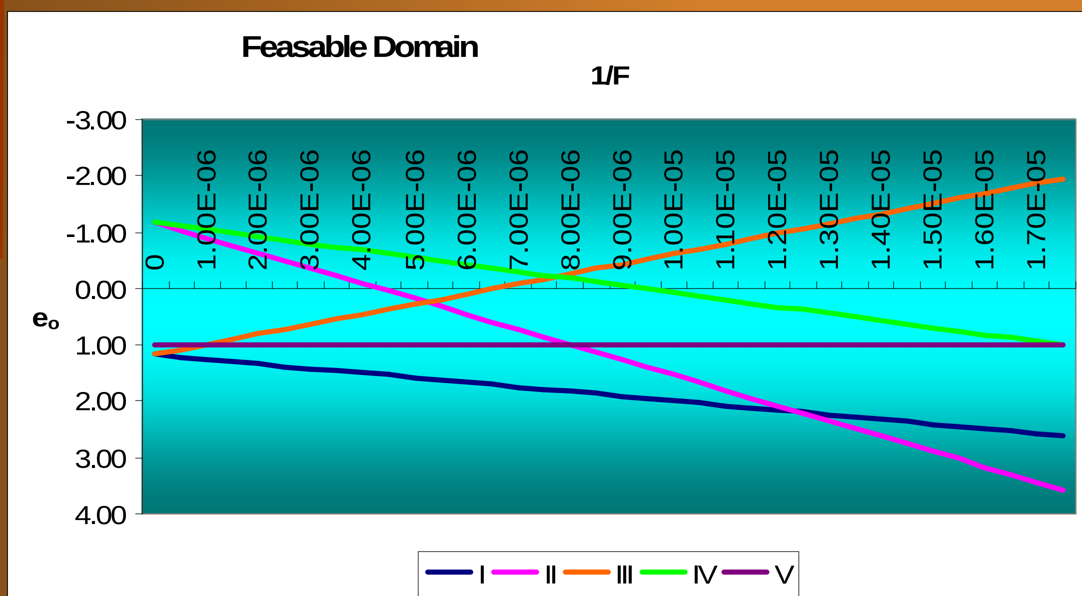
- **Structural System Redesign**
- Breath work
- Conclusions

Feasible Domain Inequalities

$e_o \bullet k_b + (1/F_i)(M_{min} – (\bullet_{ti})(Z_t))$
$e_o \bullet k_t + (1/F_i)(M_{min} + (\bullet_{ci})(Z_b))$
$e_o \bullet k_b + (1/\bullet F_i)(M_{max} – (\bullet_{cs})(Z_t))$
$e_o \bullet k_t + (1/\bullet F_i)(M_{max} + (\bullet_{ts})(Z_b))$
$e_o \bullet y_b – (d_c)_{min}$



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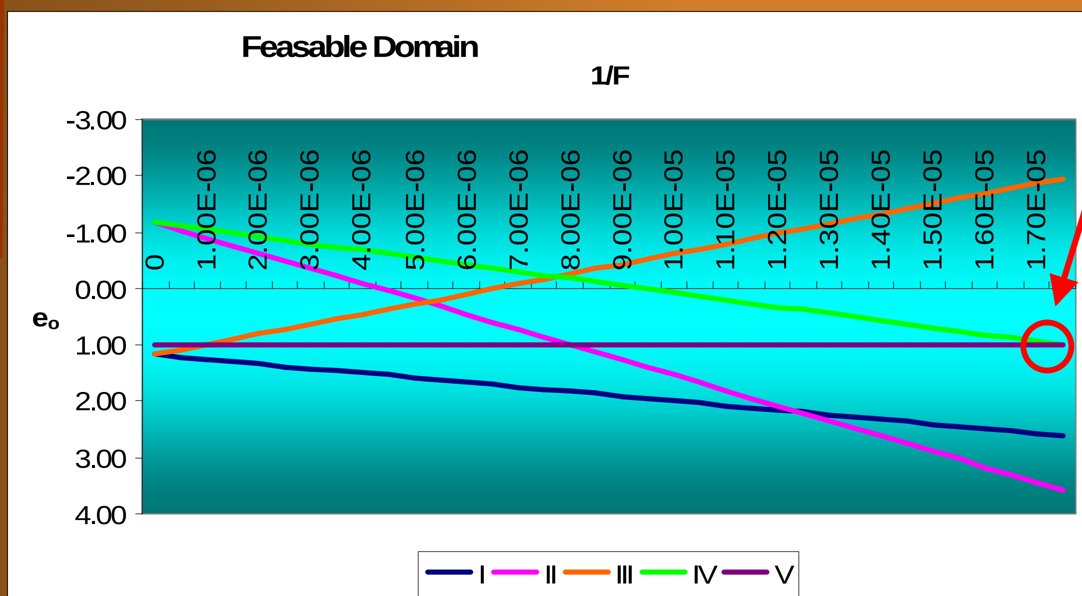
$e_o \bullet y_b – (d_c)_{min}$

Smallest force with largest eccentricity



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Post-Tensioned One-Way Slab

Flexure/Deflection

Feasible Domain Inequalities

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$e_o \bullet k_t + (1/F_i)(M_{min} + (\bullet_{ci})(Z_b))$

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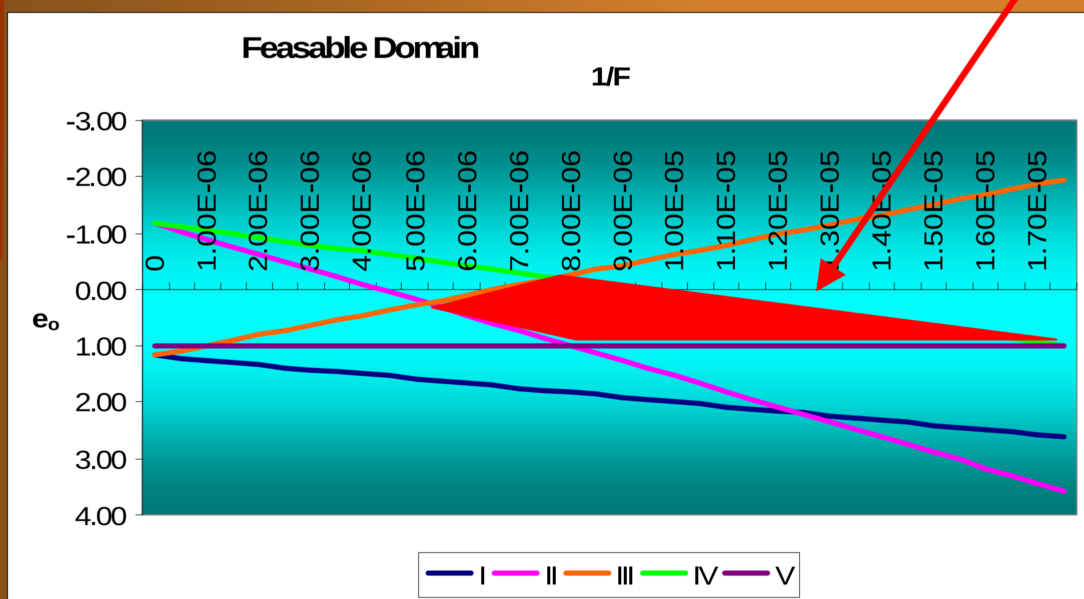
$e_o \bullet k_t + (1/\bullet F_i)(M_{max} + (\bullet_{ts})(Z_b))$

$e_o \bullet y_b – (d_c)_{min}$

Feasible Domain



Post-Tensioned One-Way Slab

Tendon Profile Parameters

Distance	Eccentricities (in)		Tendon
(ft)	Min	Max	Profile
0	-1.59	0.96	0.50
4	-0.05	1.47	0.73
8	0.85	1.78	0.97
12	1.11	1.88	1.20
16	0.74	1.78	0.97
20	-0.26	1.47	0.73
24	-1.59	0.96	0.50
28	-0.05	1.47	0.73
32	0.85	1.78	0.97
36	1.11	1.88	1.20
40	0.74	1.78	0.97
44	-0.26	1.47	0.73
48	-1.59	0.96	0.50
52	-0.05	1.47	0.73
56	0.85	1.78	0.97
60	1.11	1.88	1.20
64	0.74	1.78	0.97
68	-0.26	1.47	0.73
72	-1.59	0.96	0.50
76	-0.05	1.47	0.73
80	0.85	1.78	0.97
84	1.11	1.88	1.20
88	0.74	1.78	0.97
92	-0.26	1.47	0.73
96	-1.59	0.96	0.50

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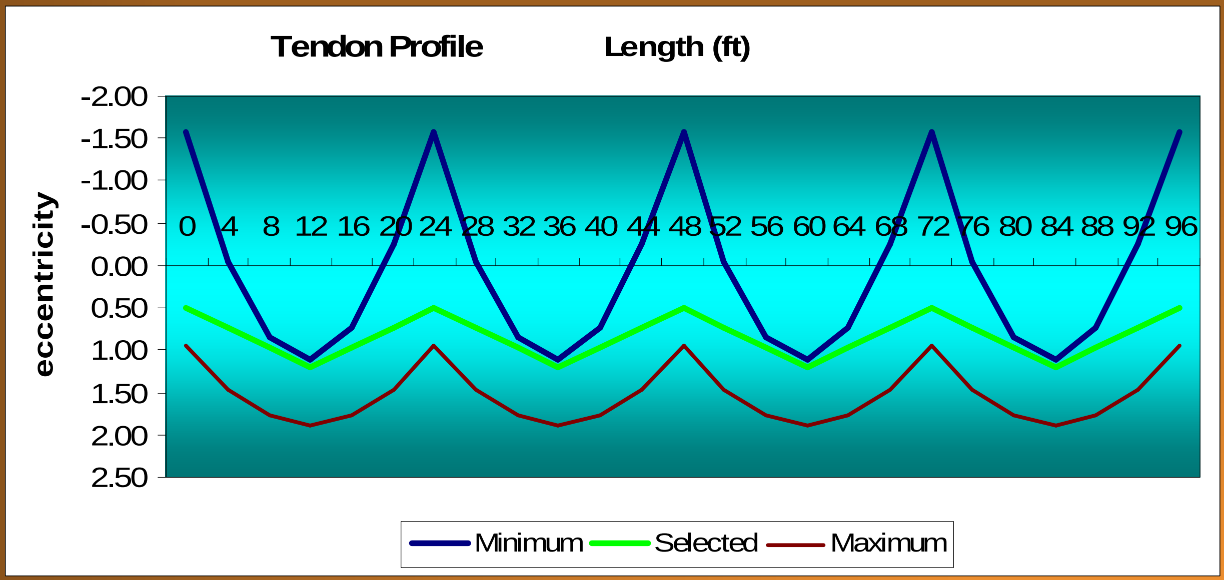

Post-Tensioned One-Way Slab

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Flexure/Deflection Results

Case Investigation	Slab Thickness	Force Required / ft
Simple Span Class U	7.5"	46.5 K/ft
Simple Span Class T	7"	56.5 K/ft
Continuous Span Class U	6"	68.3 K/ft
Continuous Span Class T	5"	70.7 K/ft

Reinforcment

(2) ½" Ø 7-wire low-lax steel strands ASTM Grade 270 were used every foot for Regions I & III

(1) ½" Ø 7-wire low-lax steel strands ASTM Grade 270 was used every foot for Regions II

Post-Tensioned One-Way Slab

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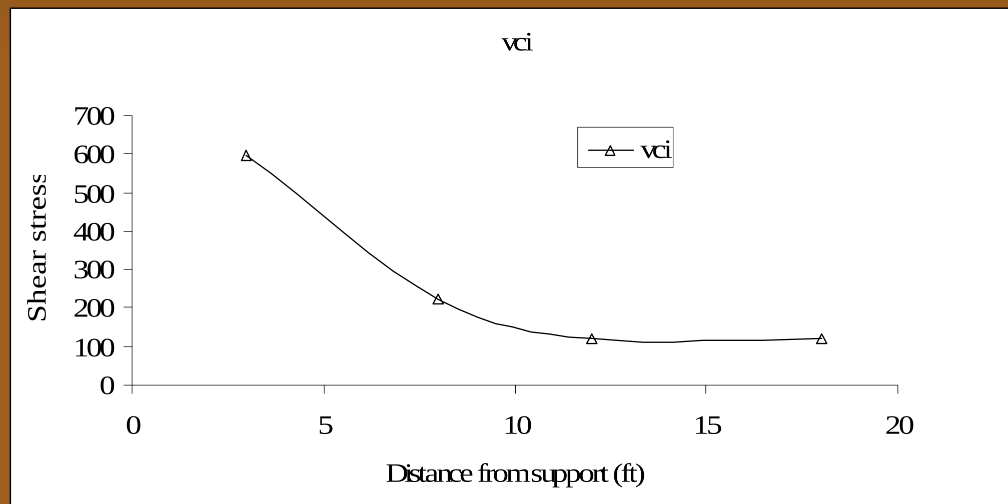
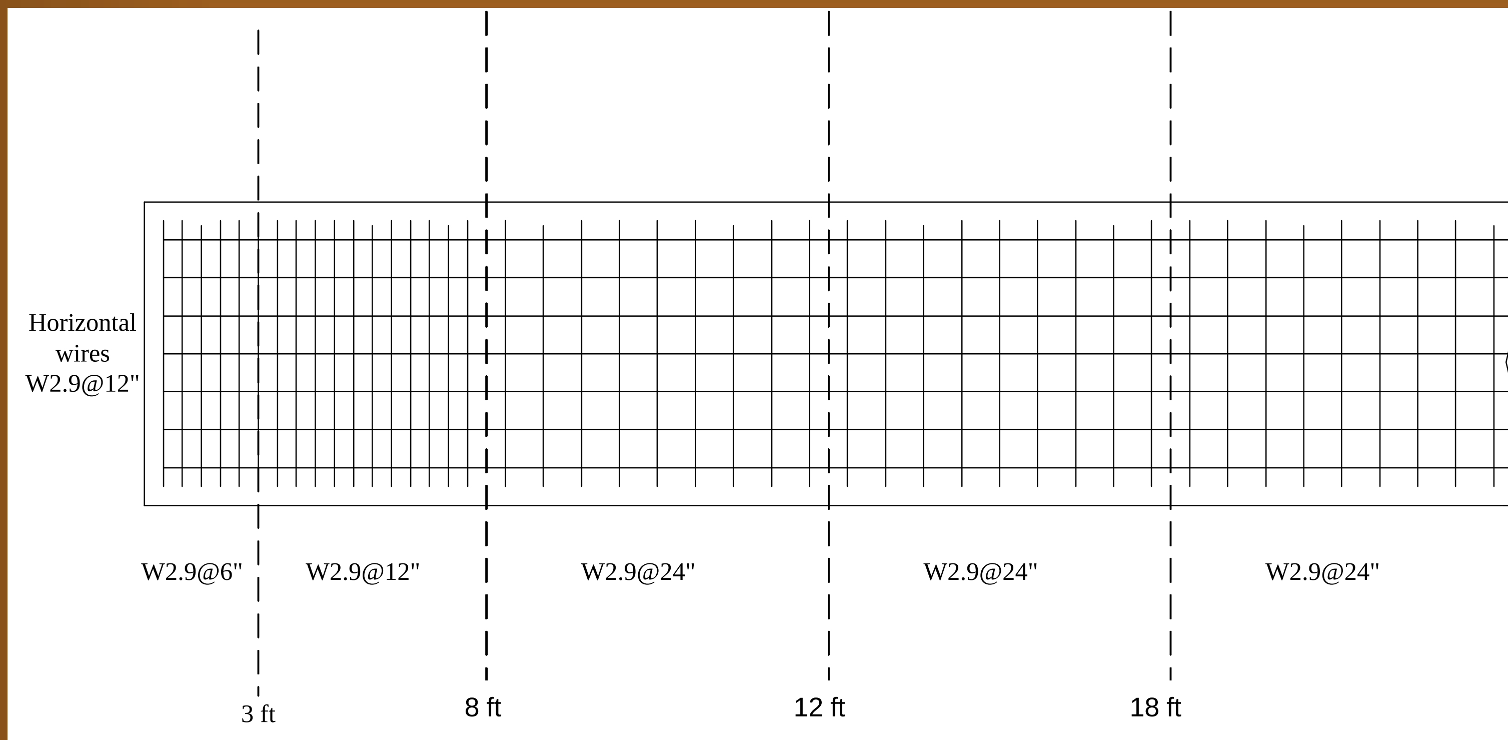
Shear



Distance from support (ft)	Wire designation	Area of shear reinforcement (in^2)	Spacing of vertical wire (in)
3	W2.9	0.058	6
8	W2.9	0.058	12
12	W2.9	0.058	24
18	W2.9	0.058	24

Post-Tensioned One-Way Slab

Shear Results



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Post-Tensioned One-Way Slab

Shear Walls

Lateral Forces (kips)						
	Wall 1		Wall 4		Wall 7	
	Shear Force	Total	Shear Force	Total	Shear Force	Total
4th Floor	7.21	7.21	1.07	1.07	5.18	5.18
3rd Floor	13.52	20.73	1.97	3.04	9.7	14.88
2nd Floor	13.48	34.21	1.98	5.02	9.67	24.55
	Wall 2		Wall 5		Wall 8	
	Shear Force	Total	Shear Force	Total	Shear Force	Total
4th Floor	6.01	6.01	2.1	2.1	1.07	1.07
3rd Floor	11.27	17.28	3.94	6.04	1.97	3.04
2nd Floor	11.23	28.51	3.93	9.97	1.98	5.02
	Wall 3		Wall 6			
	Shear Force	Total	Shear Force	Total		
4th Floor	2.56	2.56	6.04	6.04		
3rd Floor	4.79	7.35	11.32	17.36		
2nd Floor	4.77	12.12	11.28	28.64		

Post-Tensioned One-Way Slab

Shear Wall Results

	Direction	# of walls	Thickness (in)	Reinforcement
Shear 1	N/S	1	10	5 @ 24"
Shear 2	N/S	1	10	5 @ 24"
Shear 3	N/S	1	10	5 @ 24"
Shear 4	N/S	6	12	5 @ 24"
Shear 5	E/W	1	10	5 @ 24"
Shear 6	E/W	1	10	5 @ 24"
Shear 7	E/W	1	10	5 @ 24"
Shear 8	E/W	6	12	5 @ 24"

Mechanical Analysis

Existing System

Water Source Heat Pump (WSHP) System With 2 Heat Pumps on the Ground Floor and 11 Exhaust Fans

Proposed System

Energy Recovery Ventilator (ERV) System (*50% Better Efficiency than existing system*) With Both the Heat Pumps and Ventilators located on the Top Floor

Is This A Feasible Alternative to Reduce HVAC Operational Costs??

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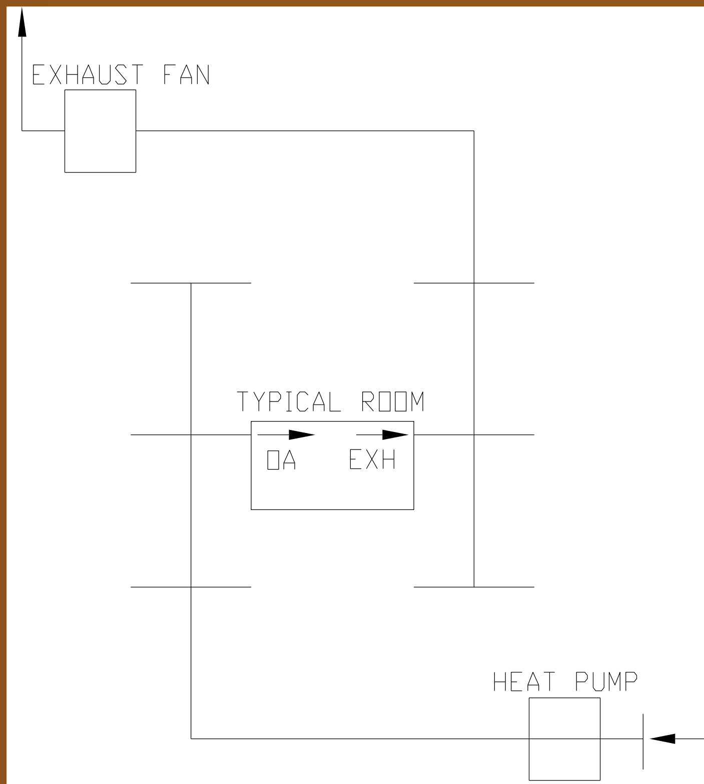
Mechanical Analysis



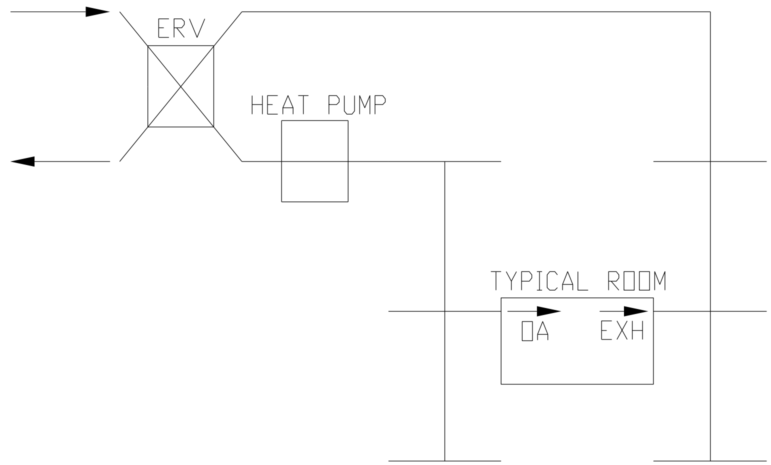


Figure 16: Existing System: Water Source Heat Pump (WSHP)

Figure 17: Proposed System: Energy Recovery Ventilator (ERV)

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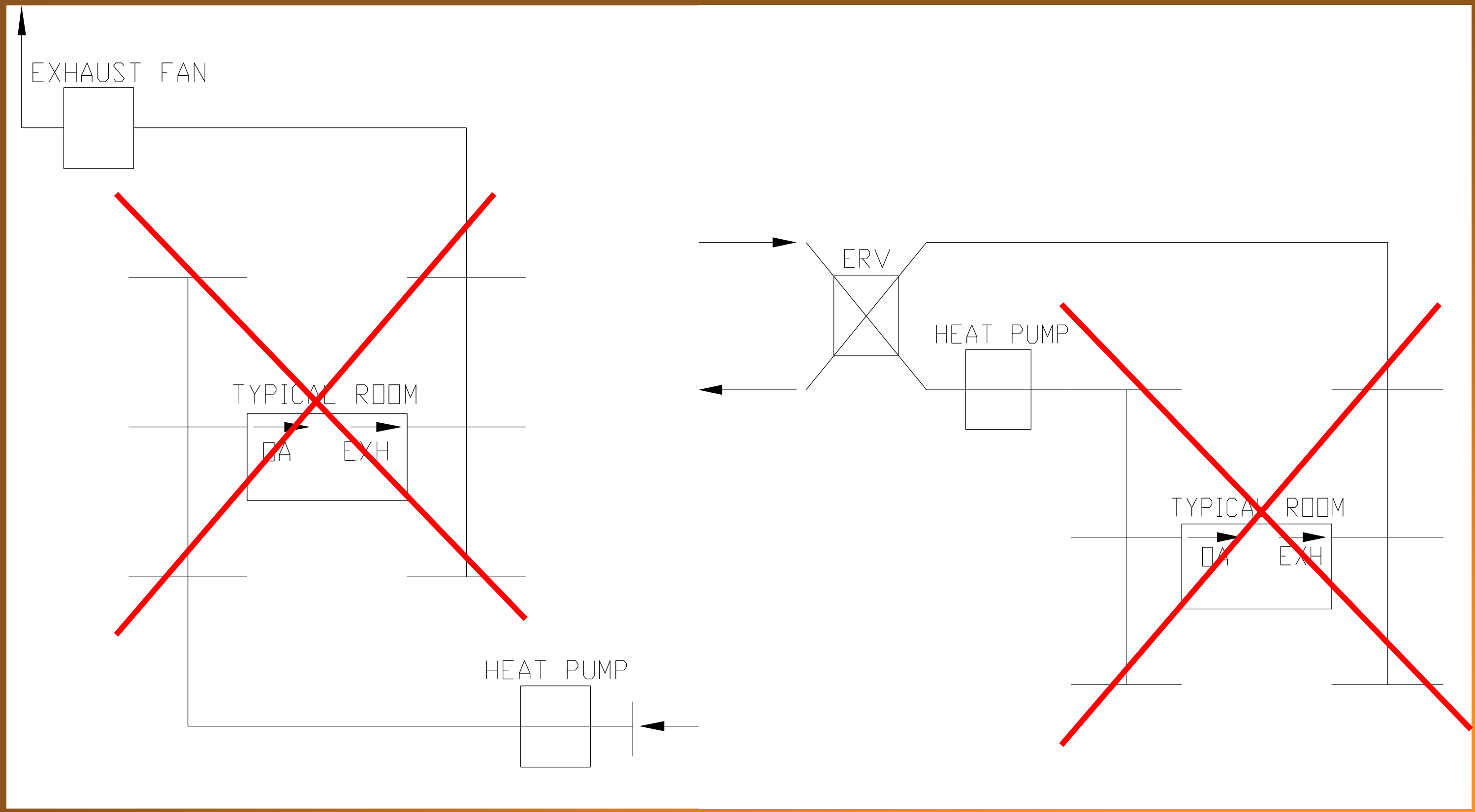

Figure 16: Existing System: Water Source Heat Pump (WSHP)

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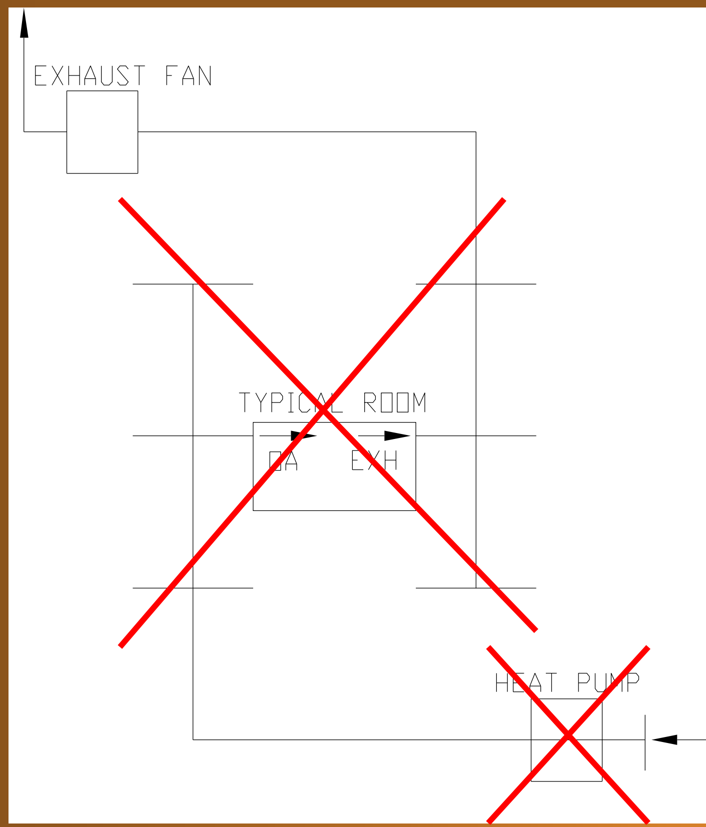

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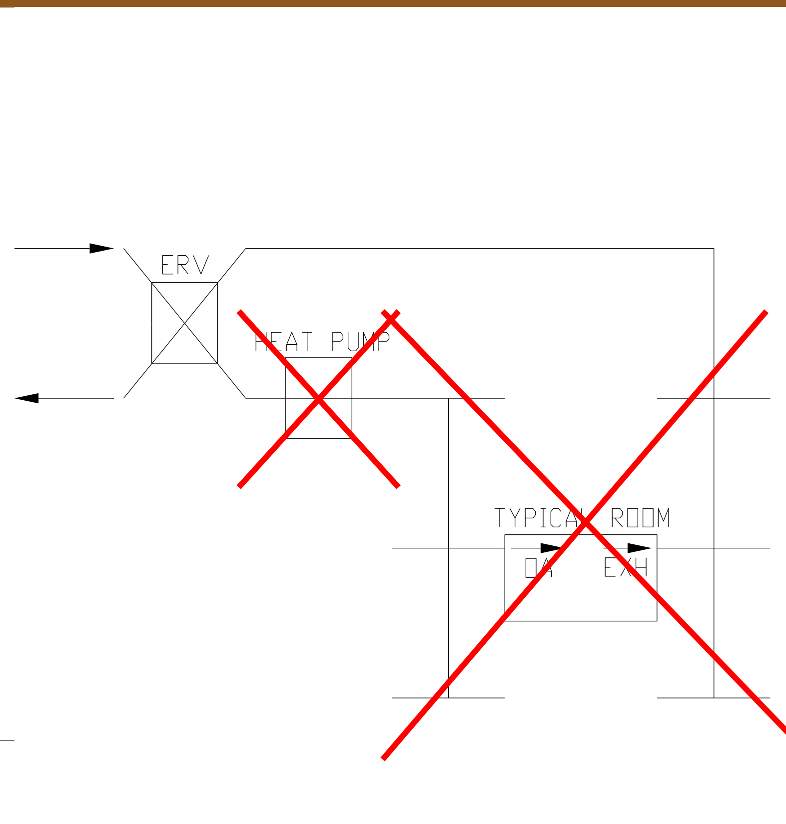

Figure 17: Proposed System: Energy Recovery Ventilator (ERV)

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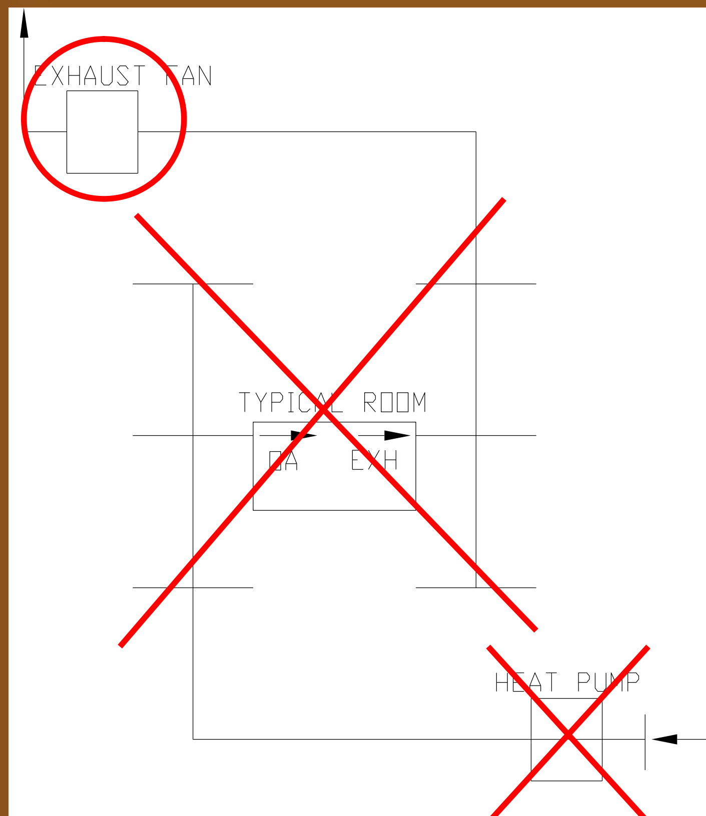

Figure 16: Existing System:
Water Source Heat Pump
(WSHP)

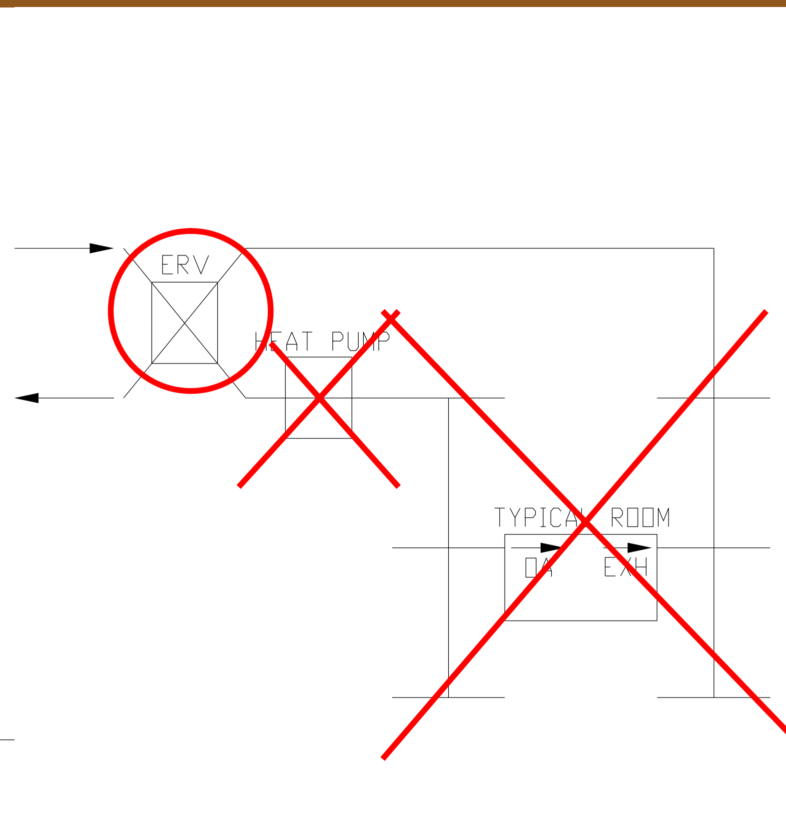

Figure 17: Proposed System:
Energy Recovery Ventilator
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RS MEANS

Cost of Running Exhaust Fans è $400 per 320 cfm

Total Savings from Eliminating Fans è $3600

Cost of ERV Unit + Installation è $3200

Total Costs of Installing ERV Units è $6400

Net Loss after ERV Installation è $2800

Sensible Heat

q = 1.08 x flow rate (cfm) x • T = 62,000 Btu/hr from exhaust

è 31,000 Btu/hr savings

Mechanical Analysis

Assumptions

Average Outdoor Temperature During the Summer in Orlando, Florida è 90° F

Desired Indoor Temperature è 70° F

It is 90° F For Approximately 150 Days Per Year and Approximately 8 Hours Per Day

Cost in Orlando, Florida è $0.10 Per KW

Solution

Amount Saved è $0.26 per hour

Time until profit made è 10,800 operating hours

è 9-10 years

Acoustical Analysis

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Part I: IBC 2000 Requirements

$STC_{minimum}$ = 50 dB

$IIC_{minimum}$ = 50 dB

Surface	Materials	STC	ICC	
Walls	8" cmu blocks	58	N/A	
Floor/Ceiling	5" concrete slab	48	25	
Interior wall	2x4 steel studs 16" o.c. w/ 5/8" gypsum board both sides	52	N/A	

Acoustical Analysis

Part I: IBC 2000 Requirements

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Surface	Materials	STC	ICC	
Walls	8" cmu blocks	58	N/A	
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Not OK

Acoustical Analysis

Solution

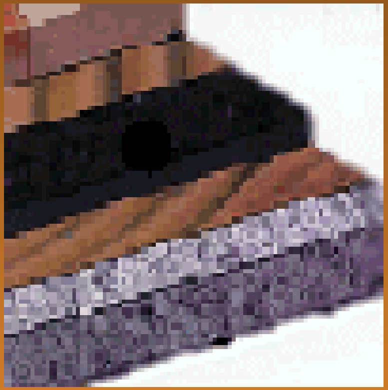
ACOUSTIK Acoustic Subflooring

2’0” x 2’0” Panels

Thickness = 5/16”

Increases STC è 65 dB

Increases IIC è 55 dB



Acoustical Analysis

Part II: AHU Check

L_{source} Calculated From Acoustics Program TAP

SA x • = a

NR = L1 – L2

TL_{actual} = NR – 10(log(a/S))

where:

SA = total surface area of the apartment (ft^2)

• = absorption coefficient

a = absorption (sabins)

NR = Noise Criteria

S = surface area of common wall (ft^2)

RC = 30 (for apartments)

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Frequency (Hz)	L_{source} (dB)	RC-value	$TL_{required}$
125	86	45	41
250	85	30	55
500	84	35	49
1000	83	30	53
2000	82	25	57
4000	80	20	60

Frequency (Hz)	• (sabins)	S (ft^2)	TL_{actual}
125	106.25	216	44
250	70.08	216	60
500	85.44	216	53
1000	94.08	216	57
2000	111.36	216	60
4000	96	216	64

TL_{actual} • $TL_{required}$

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250	70.08	216	60
500	85.44	216	53
1000	94.08	216	57
2000	111.36	216	60
4000	96	216	64

TL_{actual} • $TL_{required}$

OK

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Conclusion

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Structural

Redesign of slab allowed for longer spans increasing each unit's flexibility while minimizing the slab thickness

Redesign of shear walls to carry excess load successful

Mechanical

Proposed ERV system will provide greater savings than existing system after about 10 years

Acoustical

Using an acoustic subflooring helps new system meet IBC 2000 requirements

Rooms adjacent to mechanical rooms are sufficient to resist noise from air handling units

Acknowledgements

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AE Faculty and Staff

For all the effort, time, and input given to help us become better engineers.

TLC Engineering

For providing the plans for my building and answering all my questions throughout the year

Dr. Maria Lopez de Murphy

For all the time devoted to help me understand post-tensioned systems better.

My Family & Friends

For always believing in me and walking with me every step of the way

My wife, Franchesca

For your tireless love and confidence in me

Questions