The Regent

950 N. Glebe Road
Arlington, VA

Kristin Ruth

Structural Option

Senior Thesis Spring 2006

Presentation Outline

- Introduction to The Regent
- Overview of the Existing Structural System Design
- Proposal Summary and Design Goals
- Structural Depth Study: CIP Concrete Design
- Construction Management Breadth Study: Cost and Schedule Analysis
- Mechanical Breadth Study: Mechanical Layout Impact Analysis
- Structural System Design Comparisons (Steel vs. Concrete)
- Conclusions
- Acknowledgements and Credits

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Introduction to The Regent

- Location: 950 N. Glebe Road, Arlington, VA
- Architecture
  - 12 stories above grade - 265,243 SF
    - Office (Levels 2-12)
    - Retail (Level 1)
    - Floor to Floor Height = 13’
    - Floor to Ceiling Height = 9’
  - 3 levels of parking below grade - 158,889 SF
  - Office levels are open floor plans with a typical central core
  - Height ≈ 180 FT
- Construction Management
  - $32,000,000
  - Final completion 9-5-06

Lobby Cooper Carry Architects

Eastern Elevation Cooper Carry Architects

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Existing Structural System

- Parking Garage Structure (below grade)
  - Cast-in-place concrete columns
  - Columns on a 30’ x 30’ grid
  - Flat slabs with drop panels

- Superstructure
  - Long-span (46’/30’) composite steel beams @ 10’ o.c. with 3.25” lightweight slab on 3” composite metal deck
  - Bay sizes: 30’ x 30’ and 46’ x 30’
  - Typical beam and girder sizes: W18’s, W16’s, and W21’s
  - Typical column sizes: W14’s

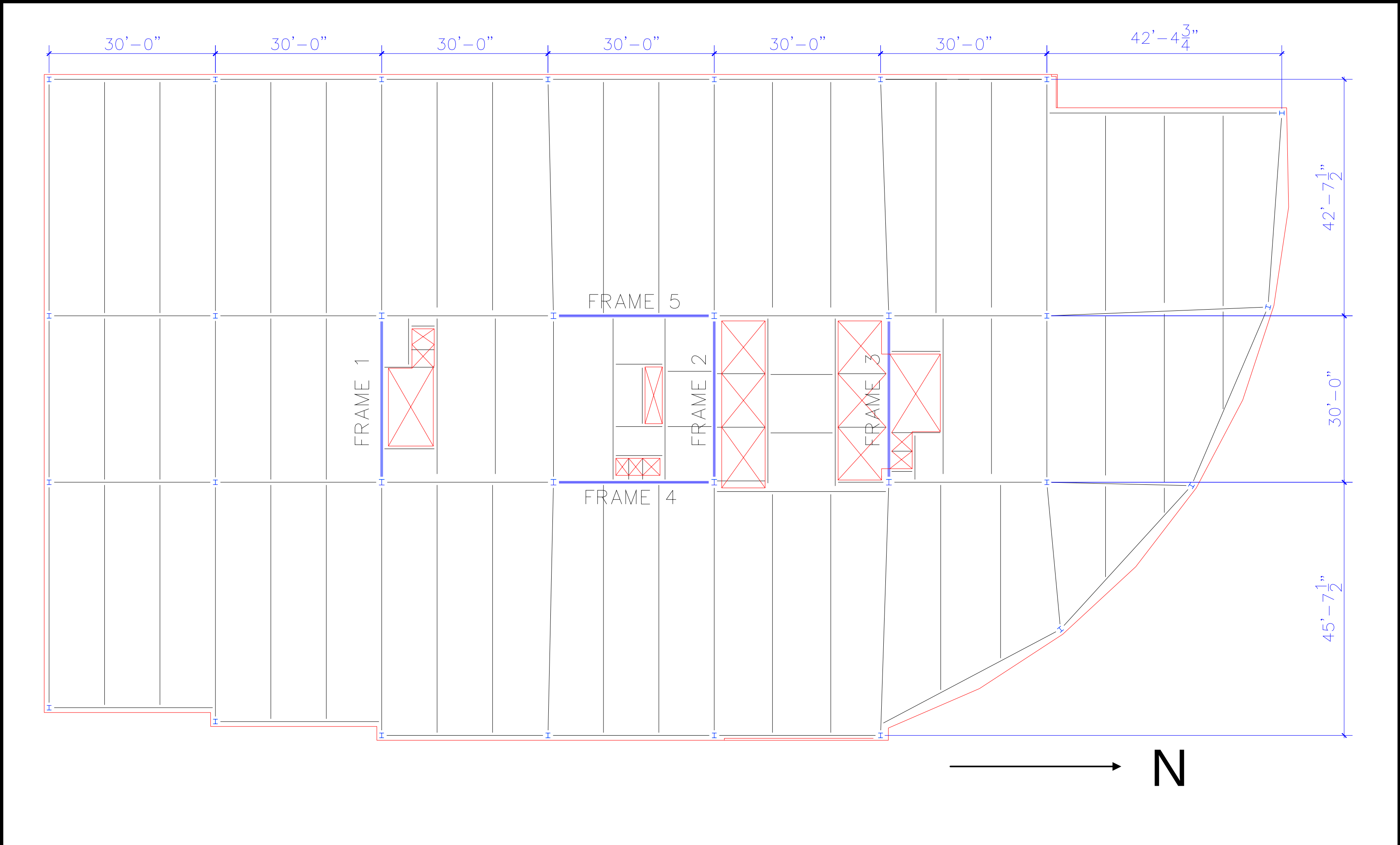
Composite Beam Floor System

Existing Structural System

- Lateral Force Resisting System
  - N/S – (2) Braced frames
    - 30’ long
    - Run the entire height of the building
  - E/W – (3) Braced frames
    - 30’ long
    - Run the entire height of the building
- Foundations
  - Square spread footings
  - Sizes ranging from 4’ x 4’ to 9’ x 9’
- Building Code - IBC 2000

Braced Frame

Typical Framing Plan (Levels 2-5)



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Proposal Summary and Design Goals

- Maintain design team’s goals
  - Minimize floor system depth
  - Maximize floor to ceiling height
  - Meet maximum height restriction ≈ 180’
  - Open floor plan with minimal column interruptions (spec office building)
  - Minimal building costs
  - Quick construction schedule
- Goal: Design an alternative system to meet or exceed most of these goals

Proposal Summary and Design Goals

- Proposed Structural System Design:
  - Gravity: CIP concrete system using wide-module joists
  - Lateral: Shearwalls

  - Can accommodate larger spans - 46'/30'
  - Concrete system depth potentially less than or similar to steel system
  - Concrete system costs may be less than today's higher steel material costs
  - Concrete systems are common in Washington D.C. area - labor, materials, equipment more readily available

Proposal Summary and Design Goals

- System Comparisons
  - CIP concrete system more efficient for The Regent?
  - Any advantages gained by using a CIP concrete system?

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Structural Depth Study Overview

- Scope (Superstructure and Foundations)
  - CIP Joist Designs
  - CIP Girder Designs
  - CIP Column Designs
  - CIP Shearwall Designs
  - Representative Spread Footing Designs
  - Roof Design
- Codes and Code Load Requirements
  - IBC 2000
  - ASCE 7-02
  - Live Loads reduced where applicable

Structural Depth Study Overview

- Design Goals and Assumptions
  - Joists, girders, and columns cast monolithically
  - Slab thickness = 4.5”
  - Joist and Girder Deflection Limits
    - Total Load – L/360
    - Live Load – L/480
  - fy = 60 ksi
  - f’c
    - Joists, Girders, Shearwalls = 4,000 psi
    - Columns = 5,000 psi (minimize column sizes)
    - Foundations = 3,000 psi
  - ACI 318-02 used for cast-in-place member designs
  - Keep existing column layout – open floor plan

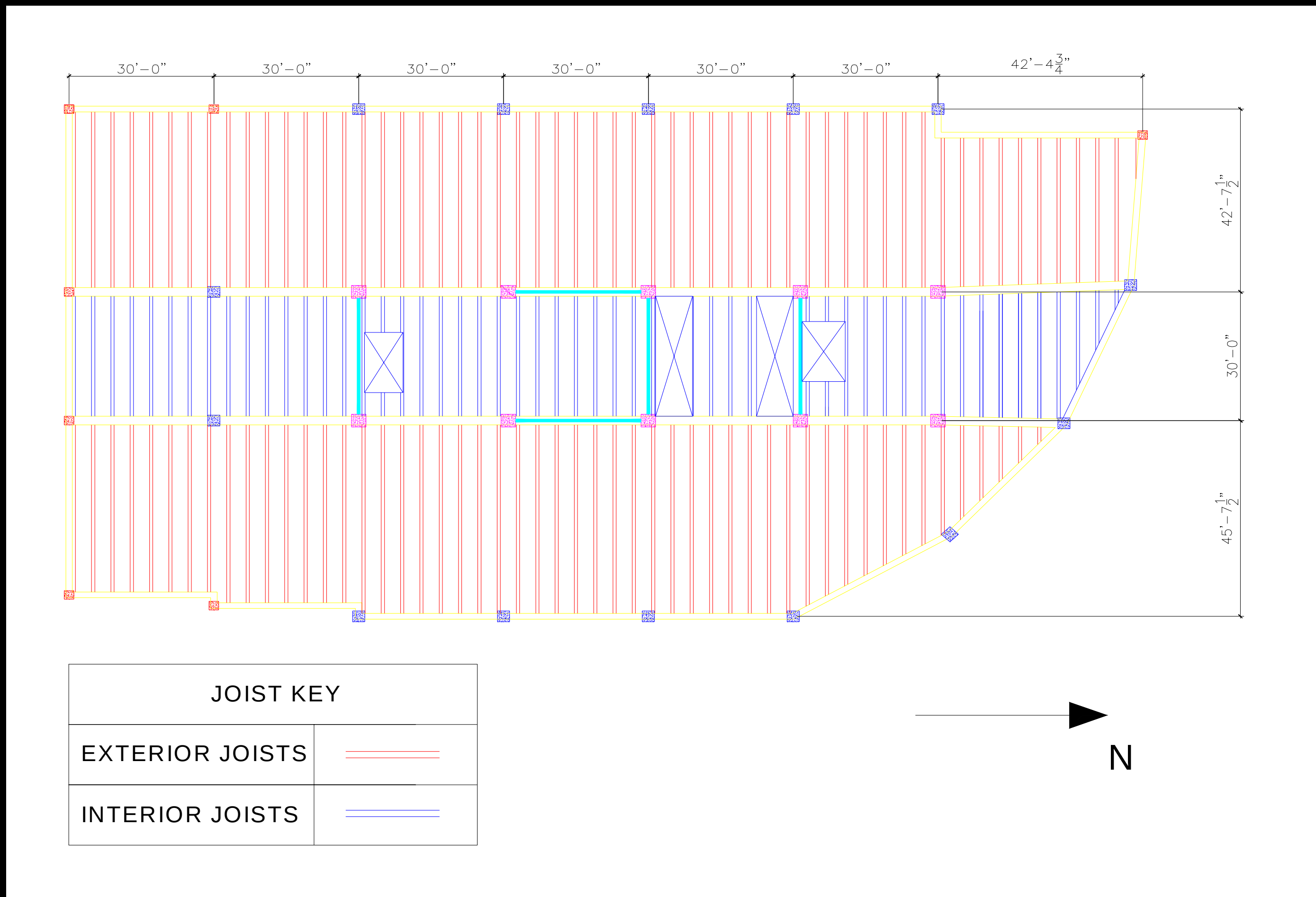
CIP Joist Designs

CIP Joist Design and Analysis

- CIP wide module joists span in the East/West direction

- Analysis
  - Design Moments and Shears
    - Moment distribution with live load pattern loading

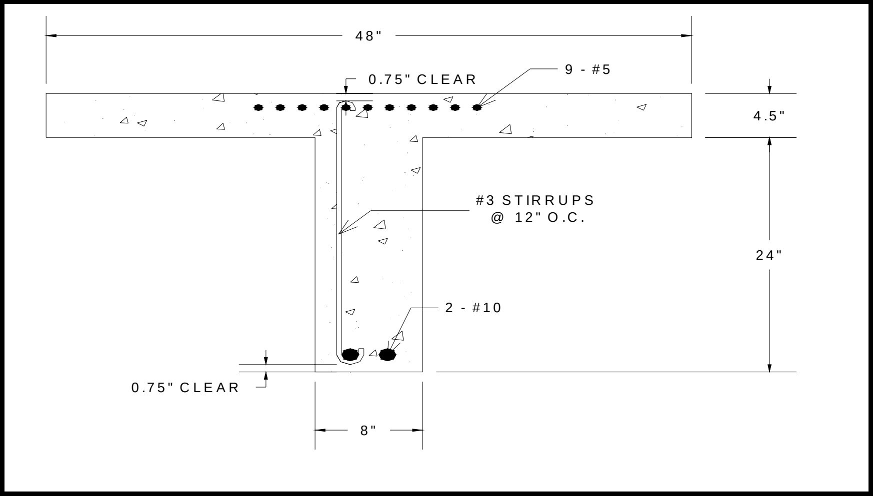
CIP Joist Layout Plan



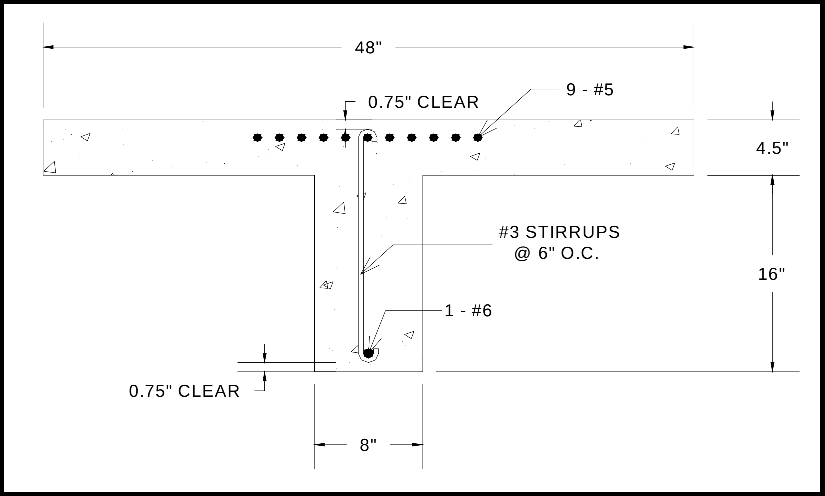
Interior Joists (30' Span)
Exterior Joists (46' Span)

CIP Joist Designs

Typical Exterior Joist Design



Typical Interior Joist Design



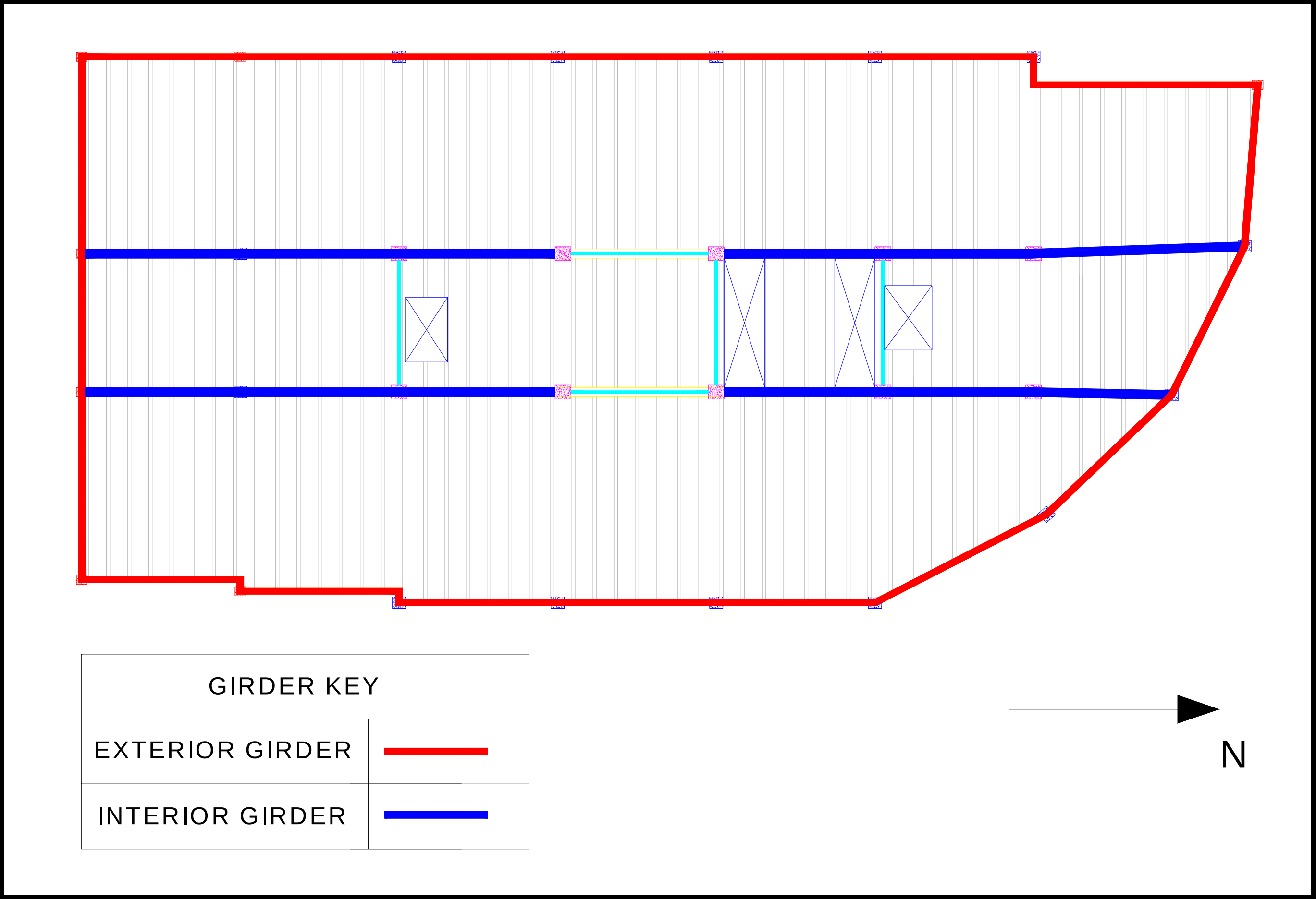
Typical Exterior Joist Design	Typical Interior Joist Design
40” Forms	40” Forms
8” ribs	8” ribs
4.5” Slab	4.5” Slab
24” Joist Depth	16” Joist Depth
Concrete System Floor Depth = 28.5”	Concrete System Floor Depth = 20.5”
Steel System Floor Depth = 24.25”	Steel System Floor Depth = 22.25”

CIP Girder Designs

CIP Girder Analysis

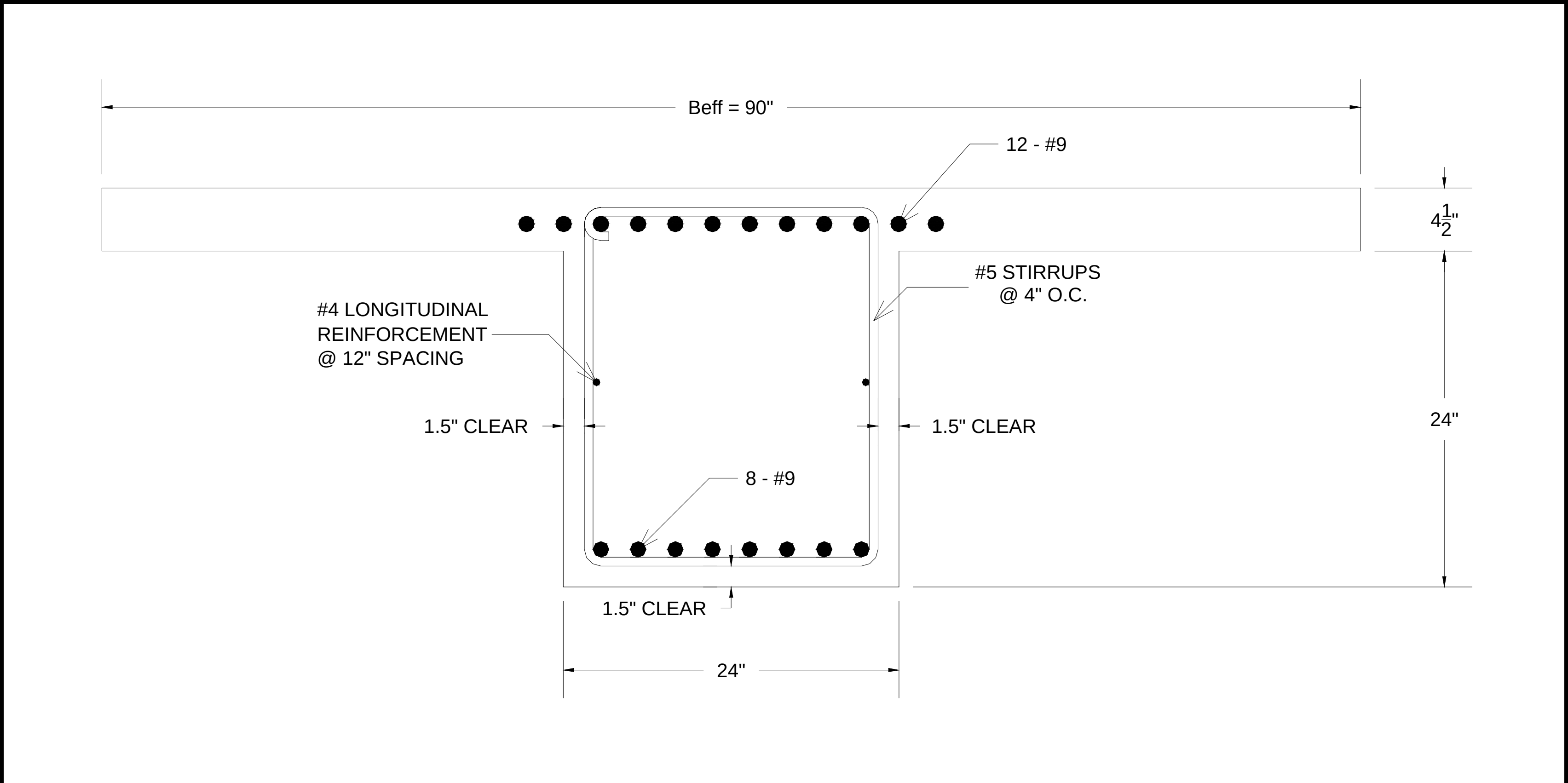
- Analysis
  - Moments
    - ACI 318-02, Section 8.3.3 moment equations
    - Portal Analysis – 25% Earthquake moments
  - Shear
    - ACI 318-02, Section 8.3.3 shear equations
  - Torsion
    - Joist FEMs

CIP Girder Design



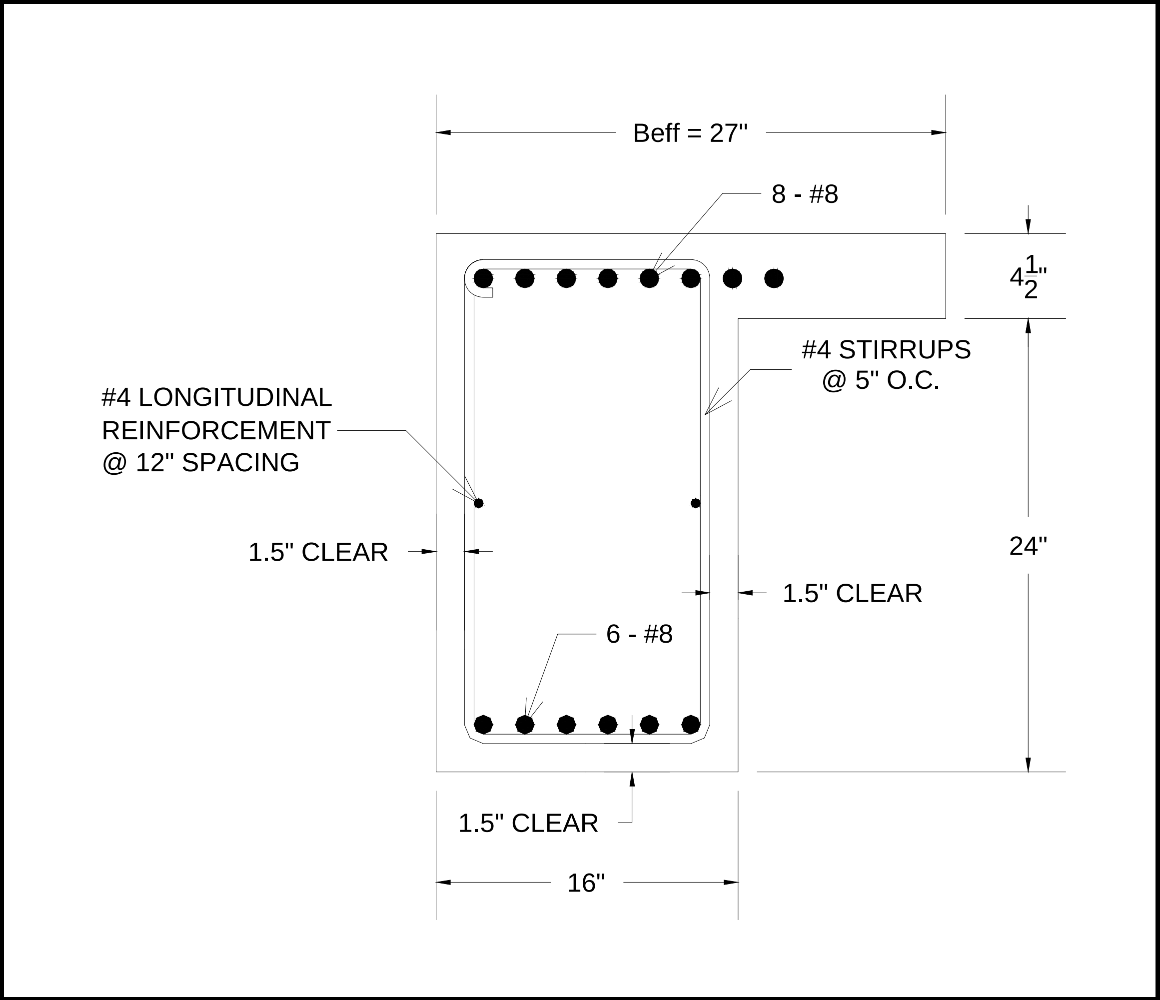
CIP Girder Designs

Typical Interior Girder Design – 24” x 28.5”



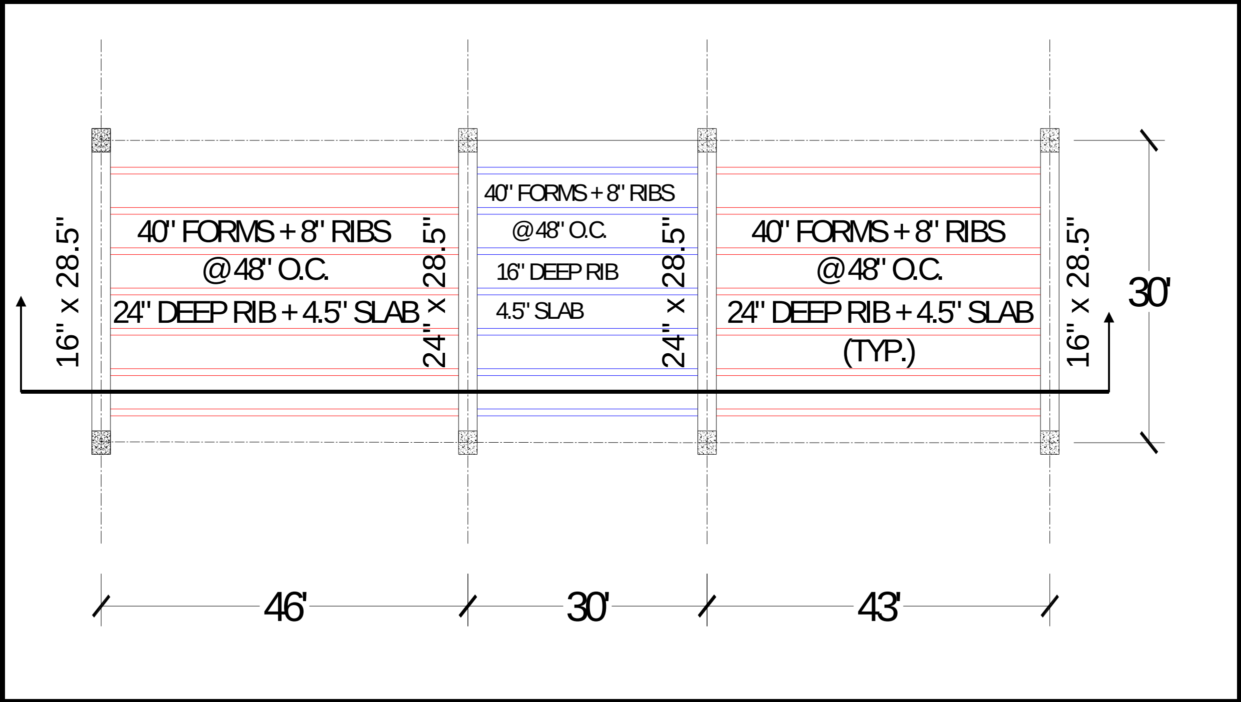
CIP Girder Designs

Typical Exterior Girder Design – 16” x 28.5”

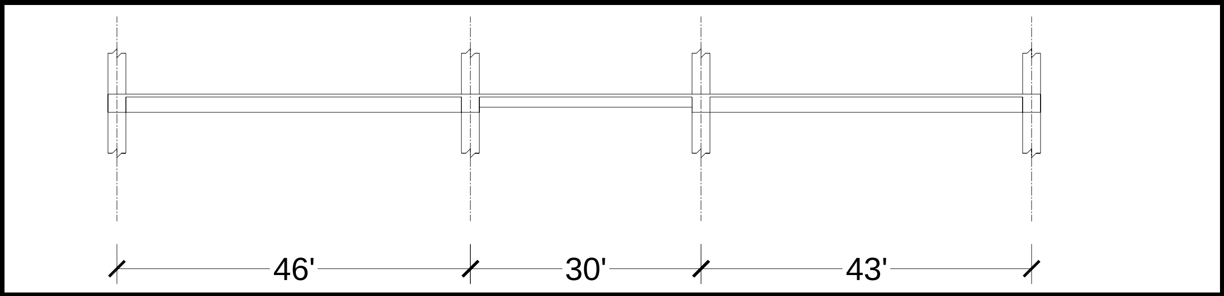


Typical Floor Bay Plan and Section

Plan

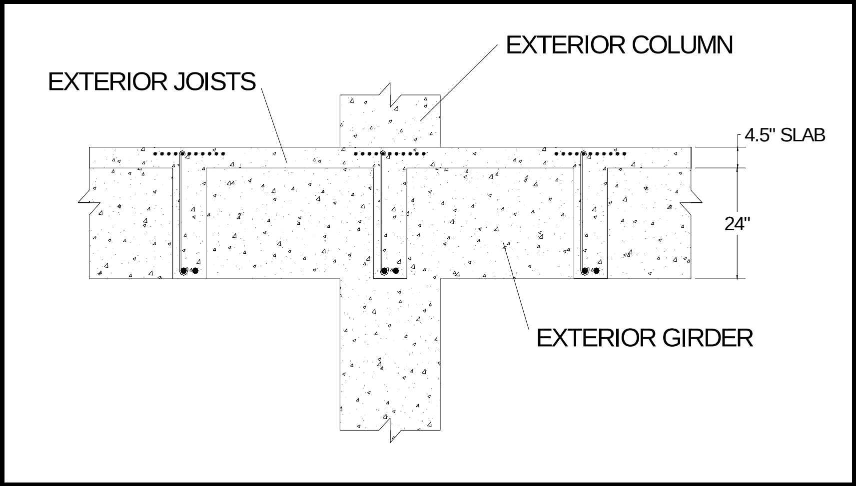


Section

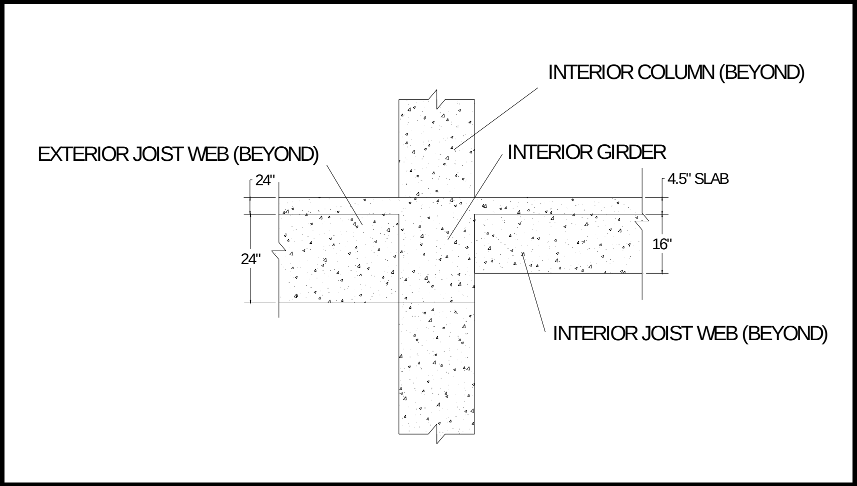


Typical Details

Typical Exterior Joist Detail



Typical Interior Joist Detail



CIP Column Designs

CIP Column Design Goals and Assumptions

- Keep same column layout
- Columns designed to take 25% of the seismic load - ASCE 7-02, Chapter 9, Section 9.5.2.2.1
- Some interior columns are boundary elements for shearwalls
- Reinforcement placed at equal spacings
- Columns designed in 3 sections at the changes in floor plan
  - Levels 1-5
  - Levels 6-9
  - Levels 10-12

CIP Column Analysis Methods

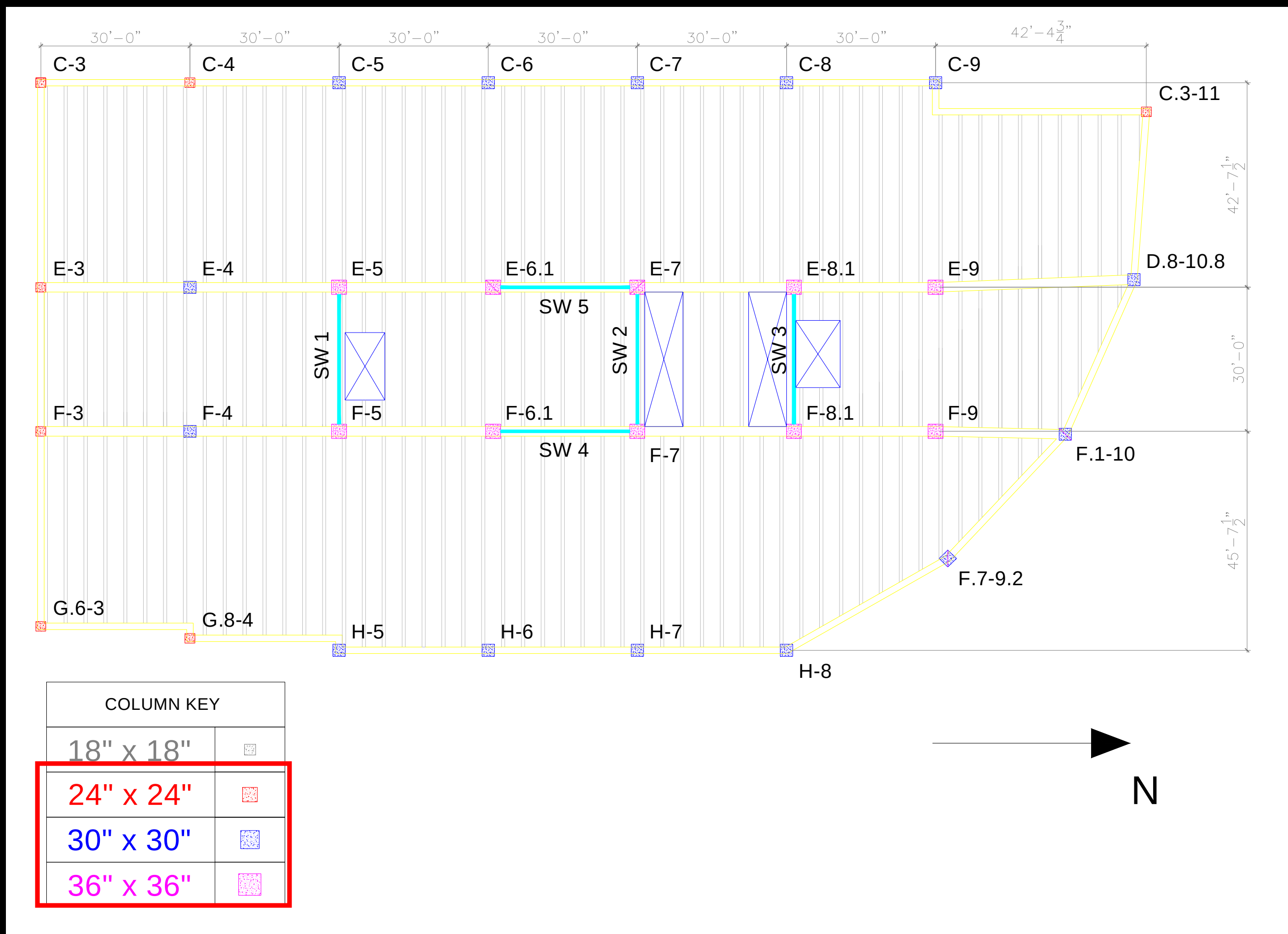
- Design Moments
  - Live and Dead Moments
    - North/South Moments: Girder moments
    - East/West Moments: Joist FEMs
  - 25% Earthquake Moments
    - Portal Analysis
- Axial Loads
  - Live and Dead Loads
    - Tributary area

CIP Column Design Procedures

- PCACOL was used for the design for each of the three column sections for each column

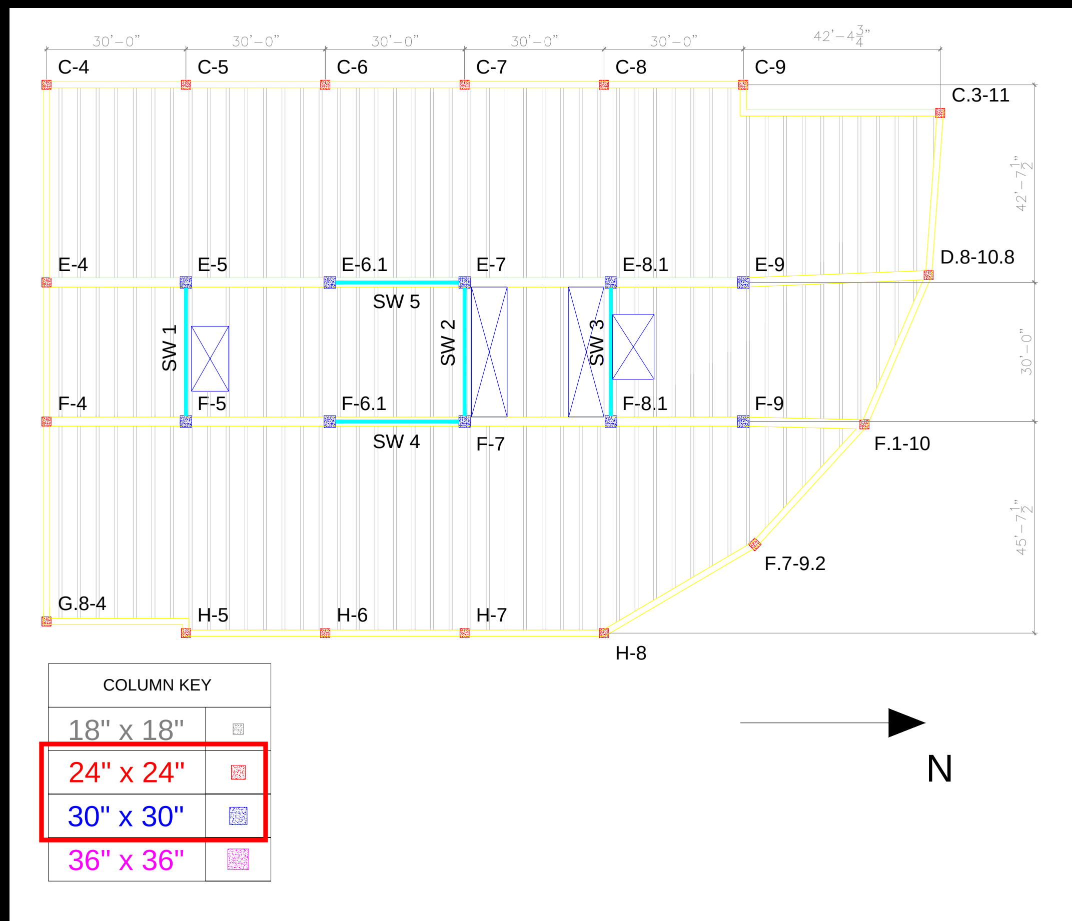
CIP Column Designs

Column Designs for Levels 1-5



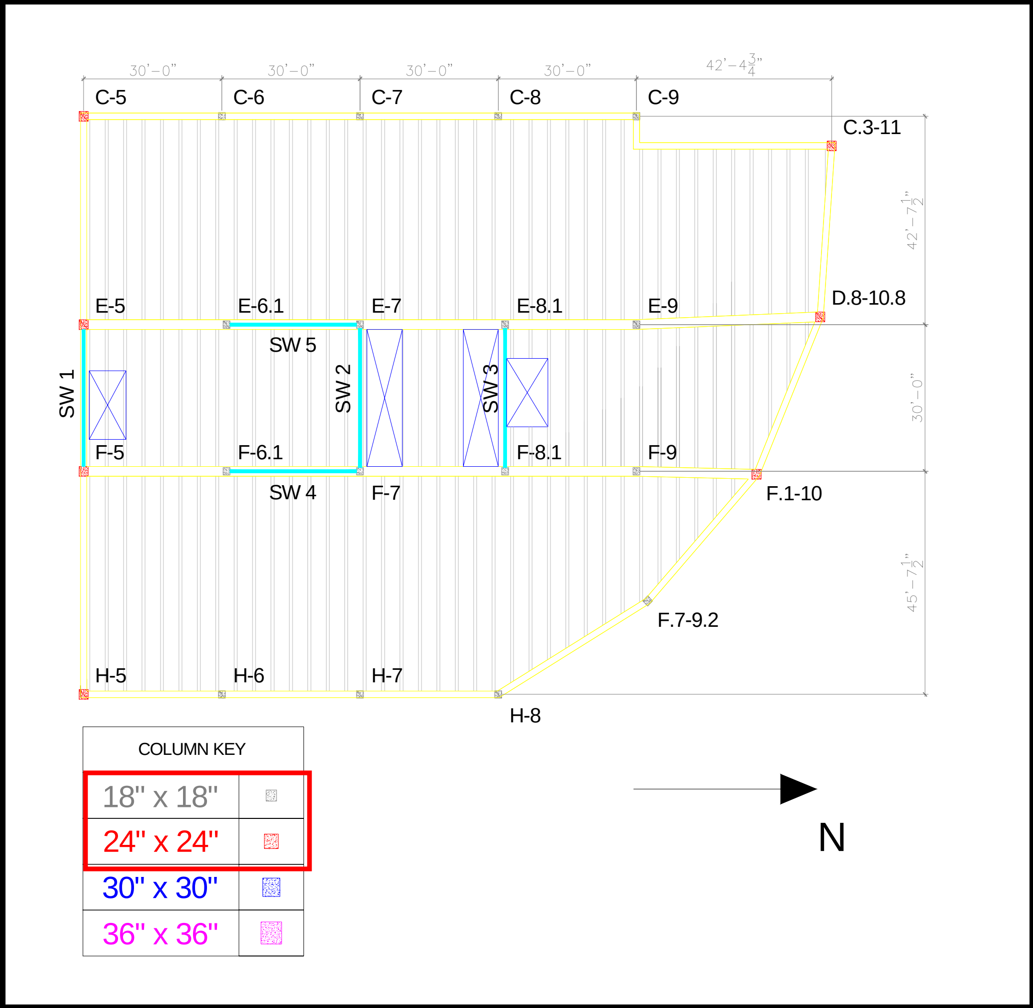
CIP Column Designs

Column Designs for Levels 6-9



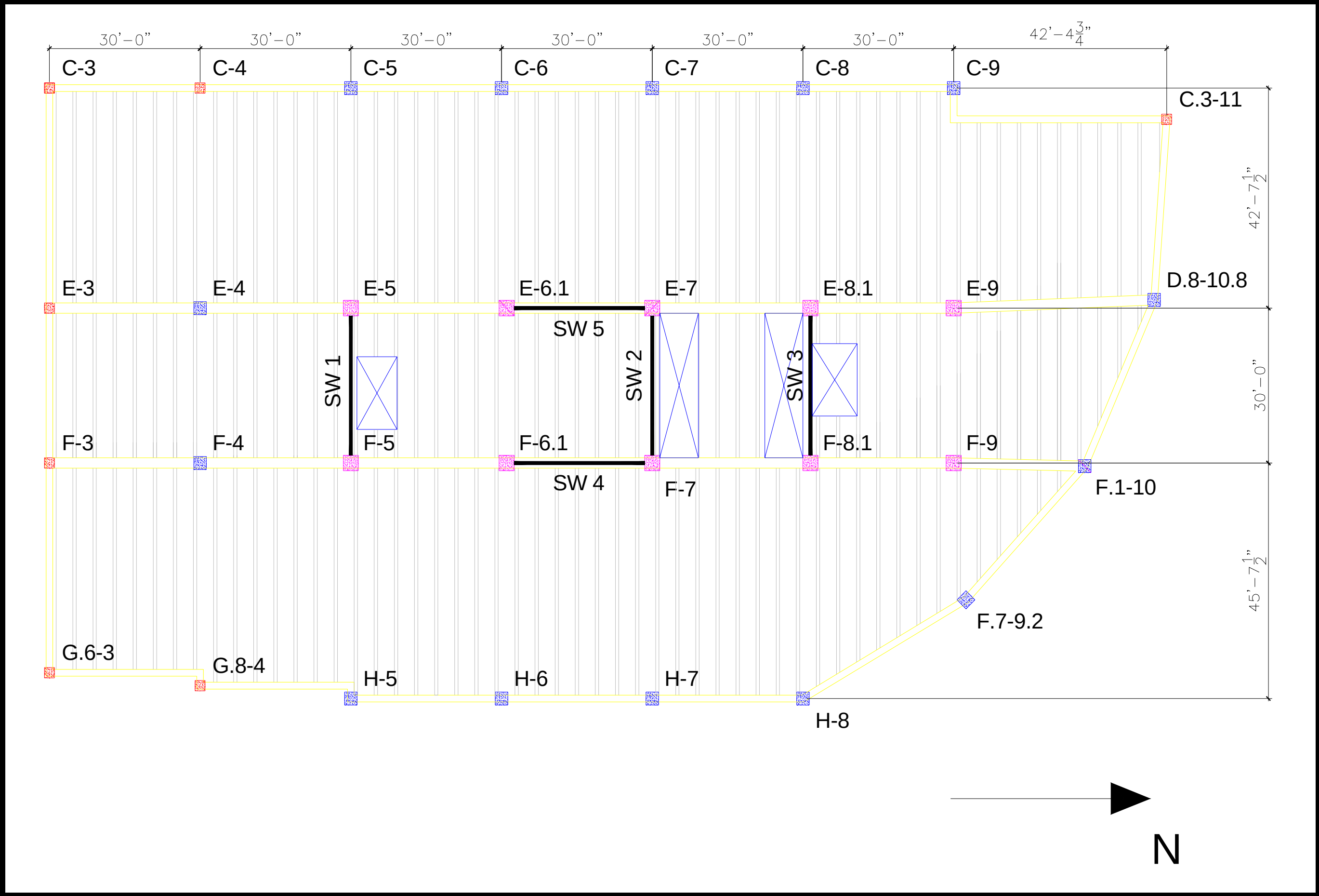
CIP Column Designs

Column Designs for Levels 10-12



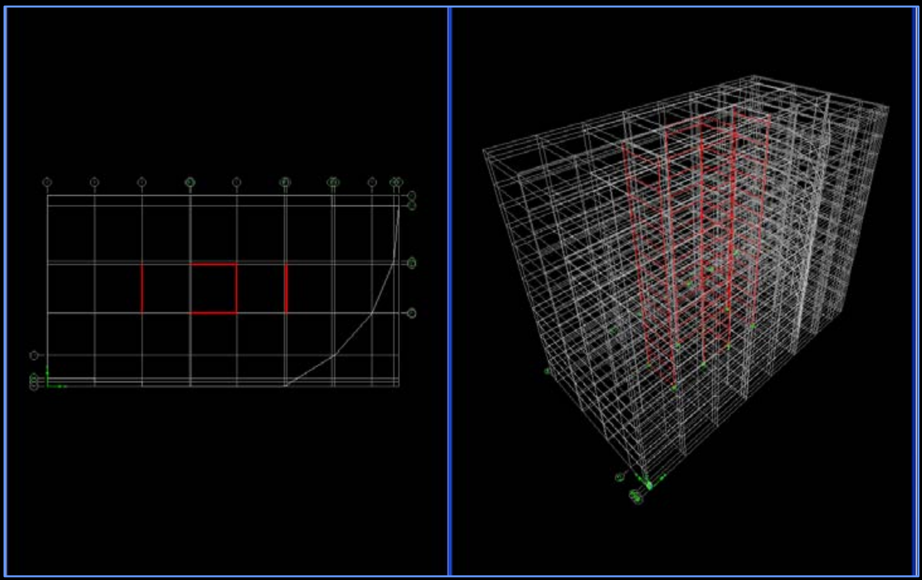
CIP Shearwall Designs

CIP Shearwall Location Plan



CIP Shearwall Analysis Methods

- Trial shearwall size – 8” (typical)
- An ETABS model used for analysis of 8” shearwall designs
- Allowable total building deflection = H/400 or 5.40”



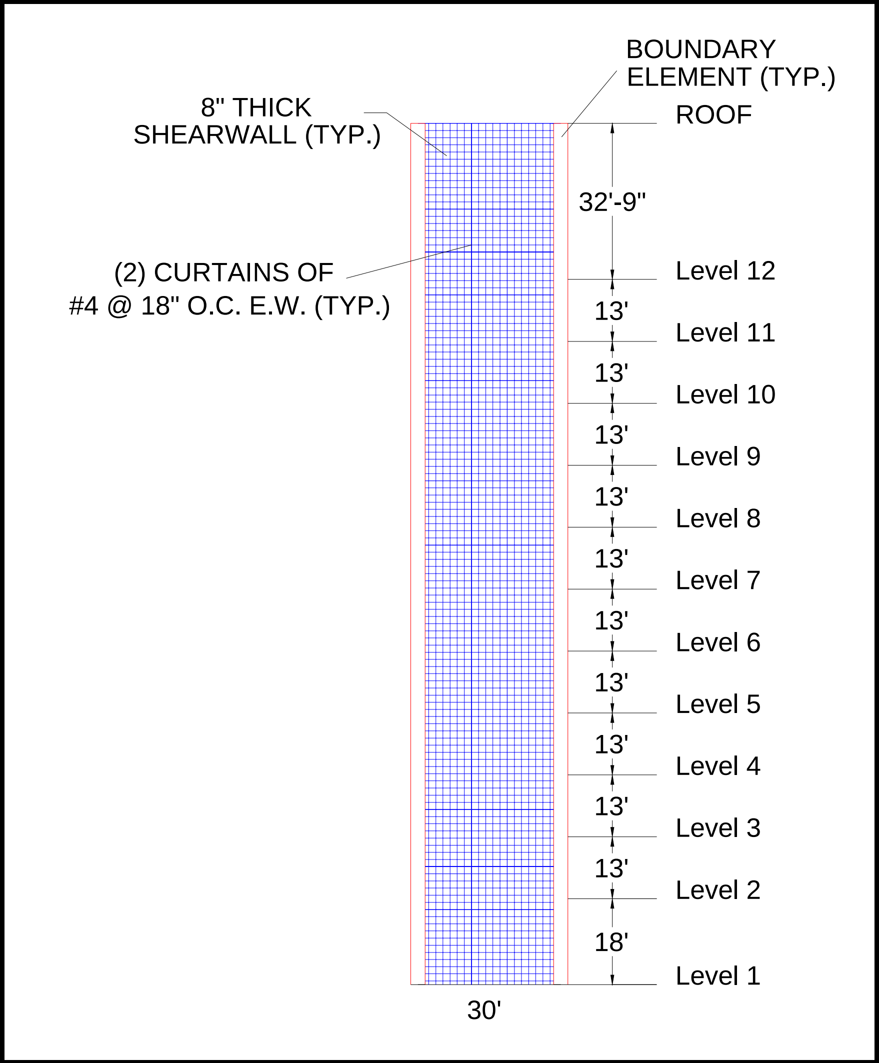
CIP Shearwall Deflections

8” Shearwalls

Wall	Max Δx		Max Δy		Max Δz	
	E/S	W/N	E/S	W/N	E/S	W/N
1	2.053982”	2.032261”	1.503888”	1.503888”	0.164363”	-0.161891”
2	2.053982”	2.032261”	1.547330”	1.547330”	0.012486”	-0.289300”
3	2.053982”	2.032261”	1.570137”	1.570137”	0.148668”	-0.150556”
4	2.053982”	2.053982”	1.526333”	1.547330”	0.424625”	0.012286”
5	2.032261”	2.032261”	1.526333”	1.547330”	0.137942”	-0.289300”

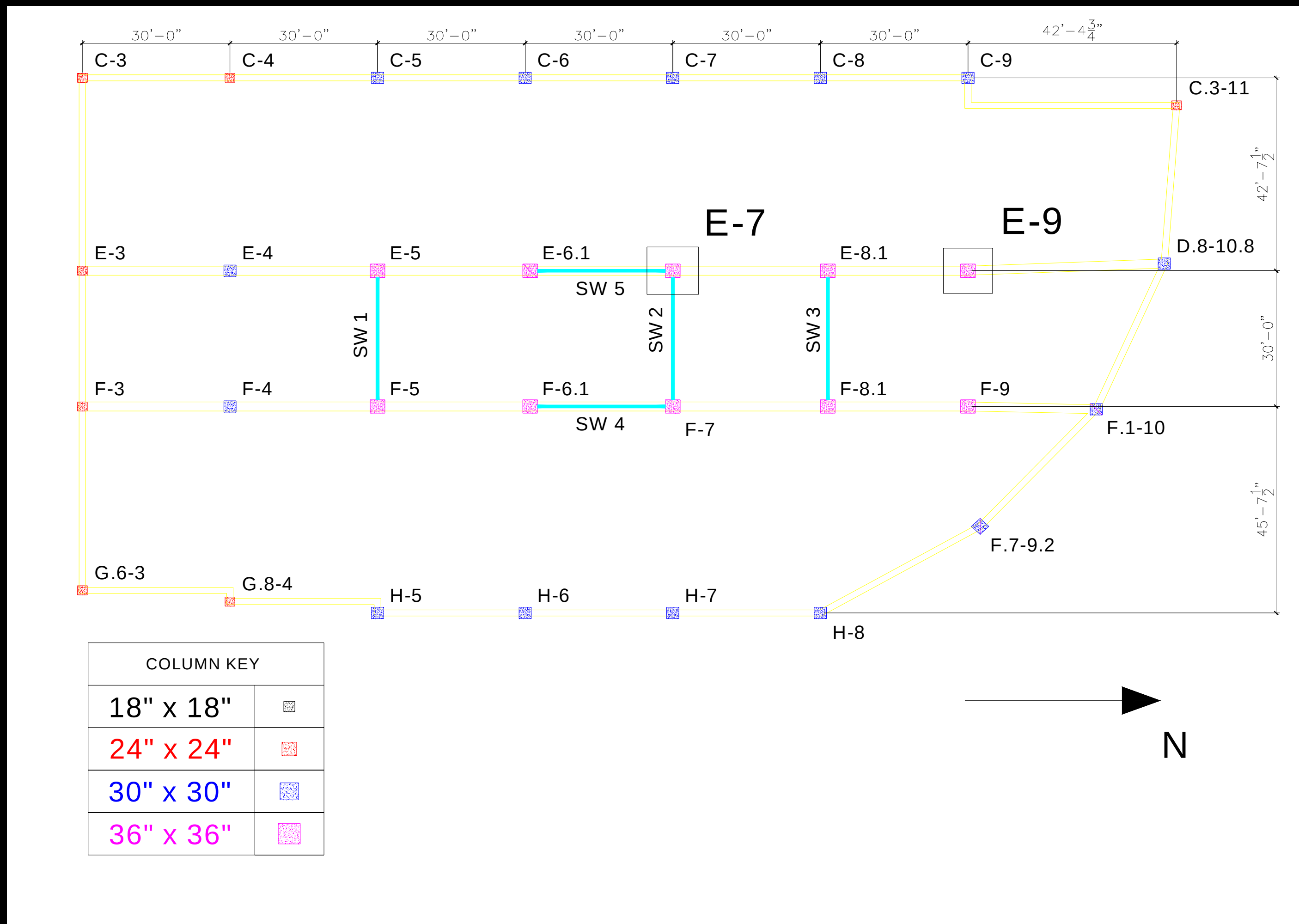
Total Building North/South Deflection ≈ 2” < 5.40” OK
Total Building East/West Deflection ≈ 1.5” < 5.40” OK

CIP Typical Shearwall Design



Representative Spread Footing Designs

Representative Spread Footing Location Plan



Representative Spread Footing Designs

- Footing E-7 - lateral force resisting and gravity column – both systems
- Footing E-9 - interior gravity column – both systems
- Allowable soil bearing pressure is 40 KSF

Representative Spread Footing Comparison: Steel System vs. Concrete System

E-7	Concrete System	10.5’ x 10.5’ x 51”
	Steel System	9’ x 9’ x 50”
E-9	Concrete System	9.5’ x 9.5’ x 45”
	Steel System	8’ x 8’ x 38”

NOTE: Concrete system footings are larger by 1.5’ in each plan dimension.

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Construction Management Breadth Study Overview

- Scope
  - Cost and schedule analysis for each system
    - Typical lower level floor
    - Representative spread footings
- Reference
  - *RS Means Building Construction Cost Data* for 2006 was used for the cost and schedule analyses

Cost Analysis

Typical Floor Cost Summary

Concrete System

Total Cost	**Concrete**		
	Material	Labor	Equipment
Joists/Slab	$225,435	$130,625	$4,543
Girders	$48,707	$58,946	$965
Columns	$24,756	$27,330	$625
Shearwalls	$8,534	$11,484	$365
Shoring/Reshoring	$149,865	$9,943	$0
	$457,297	$238,328	$6,498

$702,123

Typical Floor Cost Summary
Steel System

Total Cost	Steel		
	Material	Labor	Equipment
Slab on Deck	$41,814	$10,153	$1,881
Metal Deck	$41,468	$10,428	$728
Beams	$160,851	$9,998	$4,937
Columns	$74,396	$964	$631
Braced Members	$22,447	$1,149	$659
	$340,976	$32,692	$8,836

$382,504

Spread Footing Cost Summaries

Footing	Cost			Total Cost
	Material	Labor	Equip.	
E-7 (Concrete)	$2,052	$863	$6	$2,921
E-7 (Steel)	$1,592	$722	$5	$2,319
E-9 (Concrete)	$1,583	$701	$5	$2,289
E-9 (Steel)	$966	$464	$3	$1,433

≈$600 difference

≈$850 difference

Schedule Analysis

Typical Floor Schedule Analysis
Concrete System

Final Schedule	Concrete
	# of Days
Joists/Slab	30.31
Girders	11.03
Columns	6.36
Shearwalls	3.38
Shoring/Reshoring	6.93
	58.01

58 days

Typical Floor Schedule
Steel System

Final Schedule	Steel
	# of Days
Slab on Deck	10.36
Metal Deck	8.08
Beams	3.30
Columns	1.33
Braced Members	0.45
	23.52

24 days

Spread Footing Schedule

Footing	Schedule
E-7 (Concrete)	0.74 days
E-7 (Steel)	0.62 days
E-9 (Concrete)	0.66 days
E-9 (Steel)	0.40 days

NOTE: Concrete system footings take longer to construct.

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Structural System Comparison Chart

	Steel System	CIP Concrete System
Floor System Depth	24.25" (46' span) 22.25" (30' span)	28.5" (46' span) 20.5" (30' span)
Floor to Floor Height	13'	13'
Floor to Ceiling Height	Interior Bay – 9' Exterior Bay – 9'	Interior Bay – 9' Exterior Bay – 8'-8"
Cost of Typical Floor	$382,504	$702,123
Material	$340,976	$457,297
Labor	$32,692	$238,328
Equipment	$8,836	$6,498
Typical Floor Schedule	24 days	58 days
Cost of Foundation for Lateral Resisting and Gravity Column	$2,319	$2,921
Cost of Foundation for Gravity Only Column	$1,433	$2,289
Foundation Size for Lateral Resisting and Gravity Column	9' x 9' x 50"	10.5' x 10.5' x 50"
Foundation Size for Gravity Only Column	8' x 8' x 38"	9.5' x 9.5' x 45"
Allowable Depth for Mechanical System	Interior Bay – 14.25" Exterior Bay – 12.25"	Interior Bay – 16" Exterior Bay – 8"
Typical Floor System Weight	46 PSF	119/95 PSF
Column Sizes	W14's	18-36" SQ

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Conclusions

- Steel System is determined to be the most economical and efficient system for The Regent in comparison to the CIP system
  - Cheaper material and labor costs
  - Significantly shorter schedule (24 days/floor vs. 58 days/floor)
  - Thinner floor depth to accommodate the mechanical system layout and floor to ceiling height goals
  - Lighter system (46 PSF vs. ≈100 PSF)
  - Smaller foundations (by 1.5’ in each square dimension)

- Concrete System Advantages
  - Cheaper construction equipment costs
  - Interior bay has thinner floor system depth and greater allowable depth for the mechanical system

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- Project Team
  - Steve Sanko – Structural Design Group, Ltd.
    - Structural plans, soils report, SSKs, CAD files
  - Katie Peterschmidt – Cooper Carry Architects
  - Lauren Schlather – Cooper Carry Architects
    - CAD files, specifications, renderings
  - Kevin Gunthert – JBG Owner Representative
    - Permission to study The Regent
- AE Faculty
  - Dr. Schneider – Faculty Consultant, Fall 2005
  - Dr. Memari – Faculty Consultant, Spring 2006
  - M. Kevin Parfitt – Senior Thesis Professor
  - Dr. Boothby
  - Paul Bowers
- My fiancé Dan for his love and support
- My family for their love and support

Questions?