

The Regent

950 N. Glebe Road
Arlington, VA



Architect: Cooper Carry Architects

Proposal

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Option: Structural
Date: December 12, 2005
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Executive Summary

The Regent is located at 950 North Glebe Road in Arlington, Virginia. The building is a 12-story spec office building with retail space on the first level. There is also a 3-story parking garage below grade. The building is designed to a maximum allowable height of 176 feet. The Regent is currently under construction, and since the building was not pre-leased before construction began, the occupants or tenants are not known at this point.

Based off of the study, research, analysis, and designs of the existing system (steel framing with composite slab) and the four alternative systems (hollowcore planks with steel framing, precast double tees with precast framing, one-way wide module joists with CIP framing, and a two-way flat slab with drop panels and CIP framing), it was determined that the existing system is the most efficient design to meet the needs of the building, the project team, the schedule, and the site.

Having studied the existing steel structure all semester, I wanted to challenge myself next semester by proposing to do a redesign of this building using a concrete system. Although my initial conclusions are that the existing steel design is the most appropriate for this building, I want to do a redesign of The Regent using a concrete system in order to make comparisons between the two systems.

A concrete system design shall be selected that meets as many of the initial design team's criteria as possible in order to make a fair comparison between the concrete system and the existing steel system.

Comparisons between the two systems will be based on the following:

- Cost
- Schedule
- Constructibility
- Labor
- Floor to floor height
- Floor to ceiling height
- Lateral system performance (braced frames vs. shearwalls)
- Weight
- Impact on the foundations

In reviewing the results of the alternative floor systems involving concrete design in Technical Report 2, it has been decided to explore the following concrete system in the redesign of The Regent.

- One-way Joists, Wide Module, with all Cast-In-Place Framing

In comparison to the other concrete systems considered, this concrete system is expected to be the lightest in weight and the shallowest in depth. Another goal is to

keep the same column layout as the existing steel system in order to keep the original design intention of an open floor plan.

The existing structure utilizes a series of 5 braced frames; 2 spanning in the north / south direction and 2 spanning in the east / west direction. Since the redesign will be an all concrete system, a series of concrete shearwalls will be used as the lateral force resisting system. These shearwalls will ideally be placed around the elevator core and/or around the stairwells. Both the elevators and the stairwells are located in the central core of the building.

The loads considered for the existing design of The Regent were research, analyzed and checked throughout all of the Technical Reports. In some cases, the loads determined corresponded to the loads used in the existing design, in other cases they did not. In reviewing the loads considered for the existing design, some of the loads seemed to be very conservative such as the floor live load and the snow load, 100 PSF and 30 PSF, respectively. These conservative loadings may have been minimum requirements set forth by the structural engineer on this project. In the concrete redesign of The Regent, the loads considered will be optimized and will be based off of IBC 2000, which was the model code used in the existing design. Although a direct comparison cannot be completed between the existing design and the redesign, the optimized loads will yield a more efficient design for the new concrete design.

The design of the concrete structure will be based off of ACI 318-05: *Building Code Requirements for Structural Concrete*. Analysis for gravity loads will be completed by hand calculations and/or through the use of structural analysis and design software: ADOSS, SAP, and PCACOL. Analysis of lateral loads will be completed using SAP2000. Trial sizes based off of the preliminary designs, determined through the CRSI Handbook and hand calculations, will be inputted into the computer programs along with the newly determined, optimized gravity and lateral loads. Live loading patterns will be considered and used to properly design the concrete gravity system.

Scope of Structure to be Designed

- Floor System - One-way Joists, Wide Module
- Cast-In-Place Beams
- Cast-In-Place Columns
- Lateral Load Resisting Shearwalls
- Foundations

As part of the breadth analysis requirements, the following breadth areas have been chosen to be studied in order to help compare the two systems.

- Construction Management
 - Cost
 - Schedule
- Mechanical
 - Impact on mechanical layout

- Possible redesign of mechanical layout of necessary
- Fire Protection
 - Comparison in fire rating between the existing steel floor system and the new concrete floor system
- Acoustics
 - Comparison between the resistance to noise penetrations between the existing steel floor system and the new concrete floor system.

A schedule has been prepared describing what tasks will be completed and when throughout the semester.

Background

Building Overview

The Regent is located at 950 North Glebe Road in Arlington, Virginia. The building is a 12-story spec office building with retail space on the first level. There is also a 3-story parking garage below grade. The building is designed to a maximum allowable height of 176 feet. The Regent is currently under construction, and since the building was not pre-leased before construction began, the occupants or tenants are not known at this point.

Architecture

The Regent is a state-of-the-art, 12-story office/retail building currently under construction at 950 North Glebe Road in Arlington, VA. Below the 12-story steel structure, there is a three-level concrete parking garage below grade. The main lobby, loading dock, central plant, and retail space are located on the 1st floor.

Glebe Road is a prime location for The Regent's office and retail space. It is located just across the street from the Ballston metrorail station at the Arlington Gateway, local to Interstate 66, and not far across the Potomac River from Washington D.C..

The Regent is a steel structure above grade and it boasts its North-facing, curved glass curtain wall façade on the southwest quadrant of the intersection of North Glebe Road and North Fairfax Drive. The South, East and West façades of the building are clad in glass and precast concrete panels. The building height varies on its South side and changes height at the 6th and 10th levels.

The core of the building includes an elevator lobby, five passenger elevators and one service elevator that run from the 1st to the 12th floors, two passenger elevators that run from the lowest parking level, G3, to the 1st floor, a mechanical room, electrical room, telephone room, service vestibule, restrooms, and two stairwells. This central core is typical on levels 2-12. The office spaces on the 2nd through 12th floors are open floor plans with no interior structural partitions. There are roof terraces on top of the 1st, 5th, and 9th floors. Other architectural features include the non-structural, exterior steel roof brow that spans the 11th and 12th floors and a non-structural steel canopy on the 1st level around the retail spaces.

Since The Regent is built to its maximum height allowance, its penthouse is sunken into the 12th story and as a result the 12th story has both single story and two story spaces. The typical floor to floor height for levels 2-11 is 13' with a 9' floor to ceiling height. The floor to floor height of the 1st level is 18' and the floor to floor height in parking garage is 10'.

Existing Gravity Framing System Description

Foundations

The foundations for The Regent consist of square footings ranging in size from 4' x 4' to 9' x 9' with depths ranging from 24" to 50" respectively. They are located on a 30' x 30' square grid. The two allowable bearing pressures for the square footings are 25 ksf and 40 ksf. The southwest quarter of the building has allowable bearing pressures of 25 ksf while the other three quarters of the building have a 40 ksf allowable bearing pressure. The larger square footings are located in the central core of the building below the elevator shafts. There are also continuous 24" wide, 12" deep concrete footings under the 12" thick continuous walls. The slab on grade is 4" thick reinforced with 6 x 6, 10/10 WWF. The concrete strength for all foundations, walls, and slabs on grade is a minimum of 3000 psi.

Concrete Parking Garage Below Grade

There is a 3-level concrete parking garage below grade. The typical bay size for the three levels of below grade parking is 30' x 30'. The most common column sizes are 16" x 24" and 28" x 36" and the most common beam sizes are 12" x 24", 12" x 18", 8" x 18", and 18" x 30". All of the columns are of design strength $f'_c = 5000$ psi, although a few are $f'_c = 7000$ psi and the 28-day design strength of the beams is $f'_c = 4000$ psi. The parking garage slabs are 8" thick with a typical drop panel size of 10' x 10' x 5 1/2" and a 28-day strength of 4000 psi.

Plaza and 1st Floor Slabs

The Plaza level slab is 12" thick with 10' x 10' x 12" drop panels. The design loads for the Plaza level include a 350 PSF live load which accounts for the weight of a fire truck loading. The first floor slab is 9" thick with 10' x 10' x 5 1/2" drop panels. The Plaza and 1st floor slabs are both of strength $f'_c = 4000$ psi.

Steel Framing Above Grade

There are two typical bay sizes for the steel superstructure above grade; 30' x 30' and approximately 43' - 46' x 30'. From North to South the columns are at a 30' spacing. From East to West the columns are spaced at 46', 30' and 43', respectively. The most common column sizes are W14 x 145, W14 x 99, and W14 x 176.

The most common beam sizes are W18 x 50, W18 x 46, and W16 x 26 with cambers ranging from 3/4" to 2" which are designed to 75% dead load. The most common girder sizes are W18 x 65, W24 x 55, W24 x 62, and W24 x 55.

The typical floor slab is 3 1/4" light weight concrete with an $f'_c = 3000$ psi and is reinforced with 6 x 6 10/10 WWF on top of a 3" - 20 gage composite steel deck for a

total slab thickness of 6 1/4". Headed shear studs, 3/4" in diameter and 5" in length, allow for composite action between the slab on deck and the supporting beams.

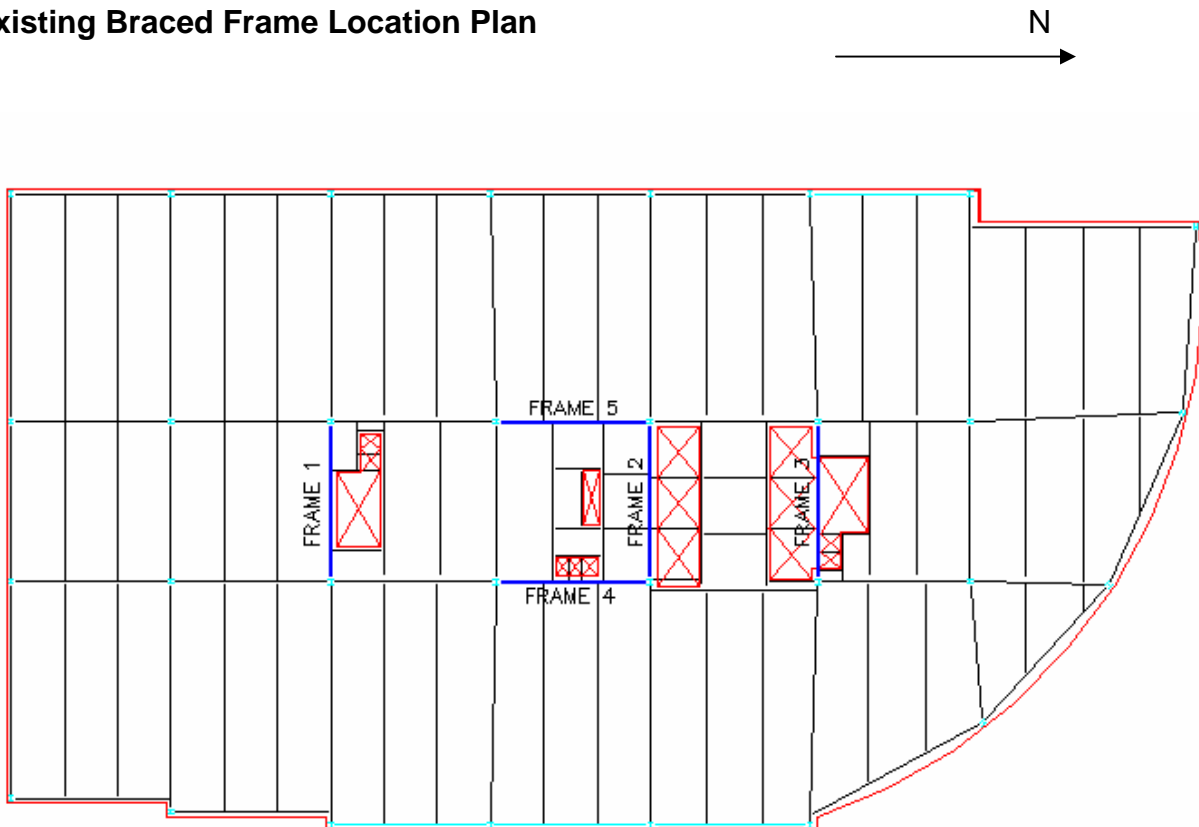
There is an elevator core running up the center of the building and through the center of each floor. The roof deck construction is 3" x 22 gage, deep rib, type N, painted roof deck.

Existing Lateral System Description

The lateral load resisting system for The Regent consists of five braced frames at the core of the building. There are two braced frames, Frame #4 and Frame #5, that span along the building's north / south axis, and three braced frames, Frame #1, Frame #2, and Frame #3, that span along the building's east / west axis. Frame #1, Frame #3, and Frame #5 have chevron style bracing and Frame #2 and Frame #4 have single diagonal bracing. The braced frames are approximately 30' in width and run the full height of the building from the first floor to the penthouse roof.

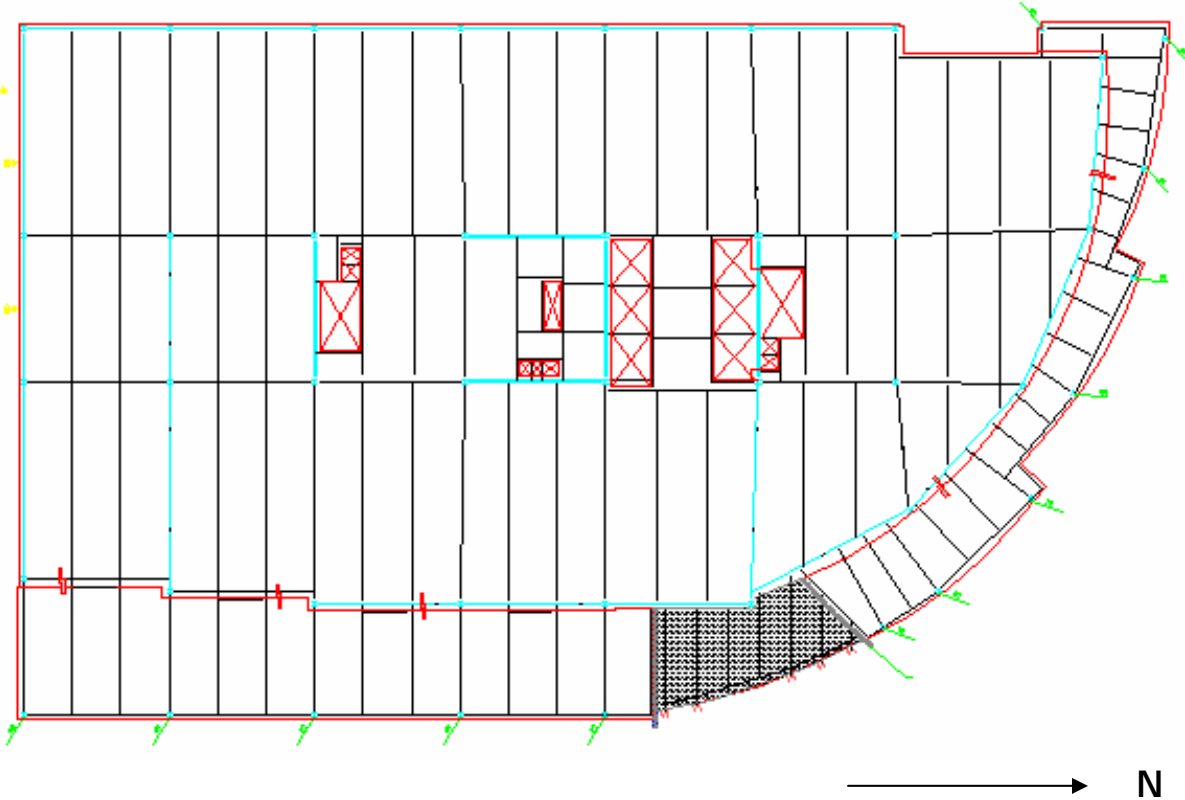
The typical diagonal steel members used in the braced frames are HSS 8" x 8"s, 10" x 10"s, and 12" x 12"s with thicknesses ranging from 3/8" to 5/8". The columns in the braced frames are all 14" wide flange members ranging in size from W14 x 233's and W14 x 257's near the base to W14 x 53's to W14 x 72's at the top.

Existing Braced Frame Location Plan

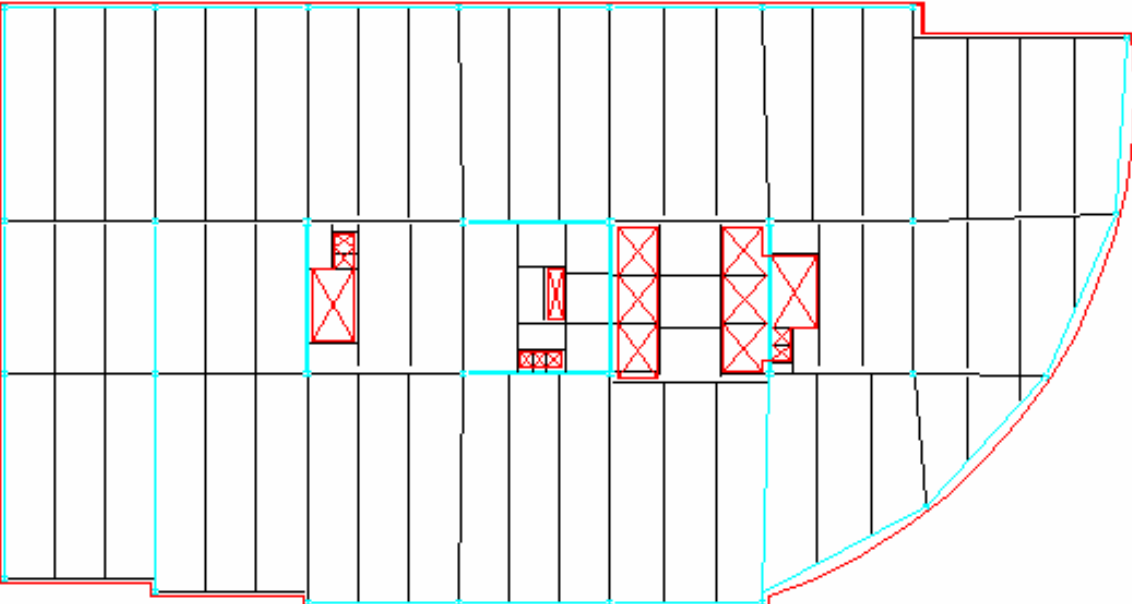


Existing Typical Framing Plans and Elevations

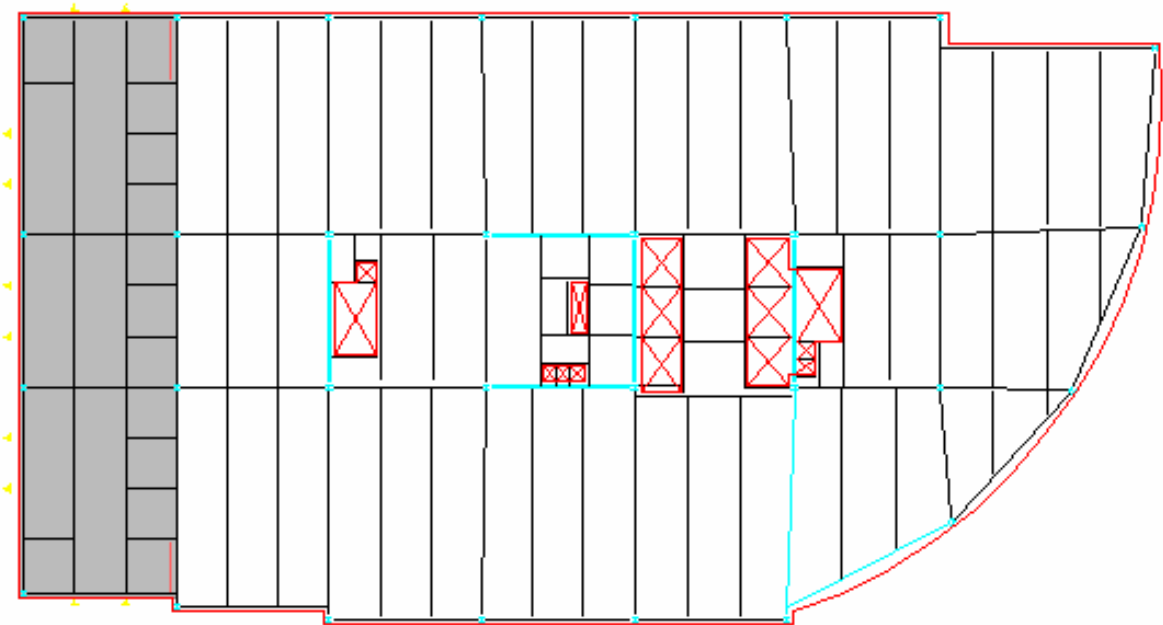
2nd Floor Framing Plan



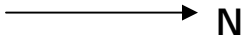
3rd – 5th Floor Framing Plan



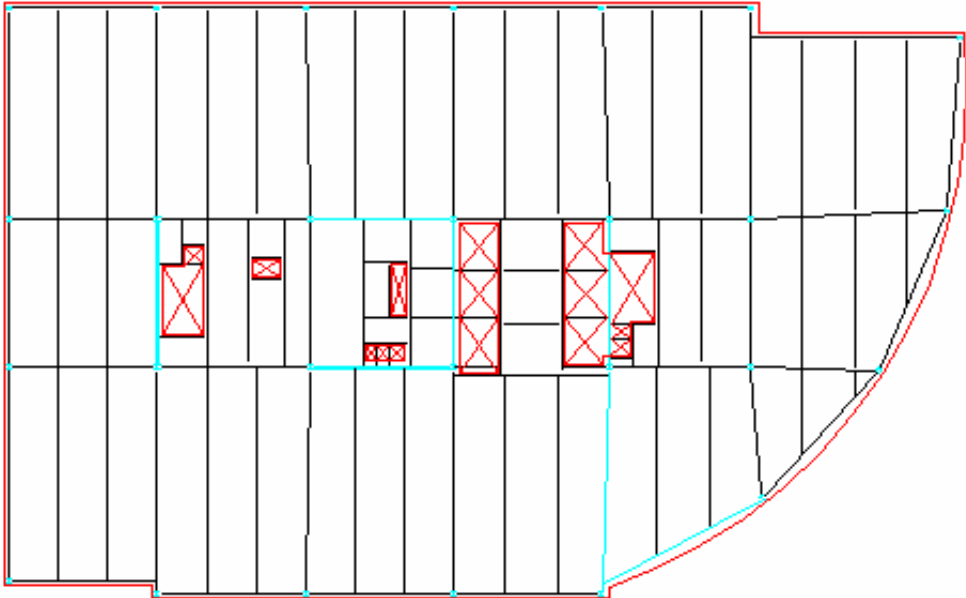
6th Floor Framing Plan



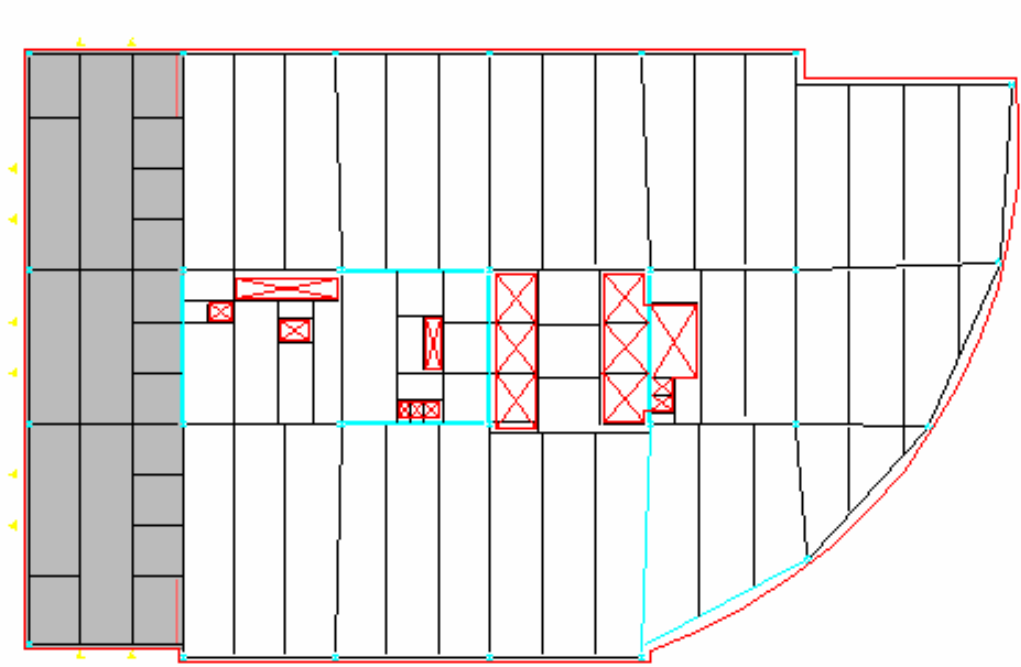
Note: Shaded area is roof construction



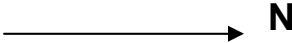
7-9th Floor Framing Plan



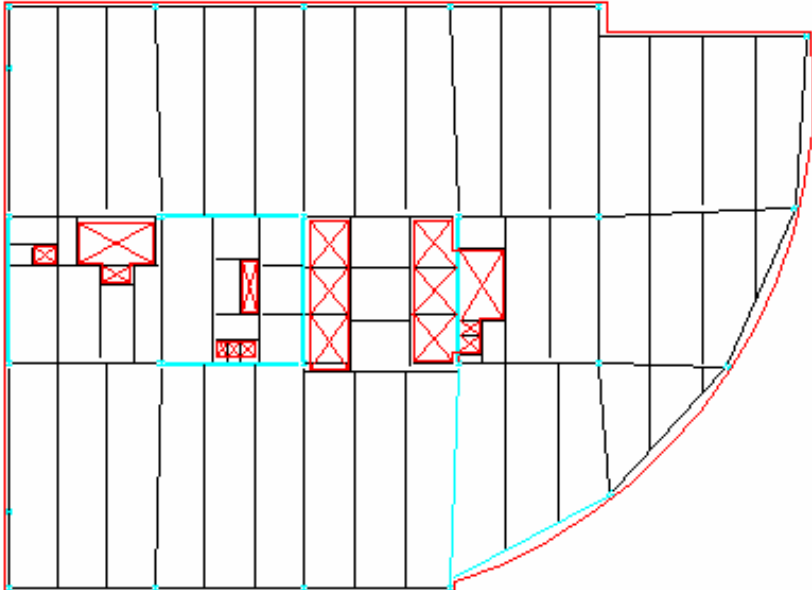
10th Floor Framing Plan



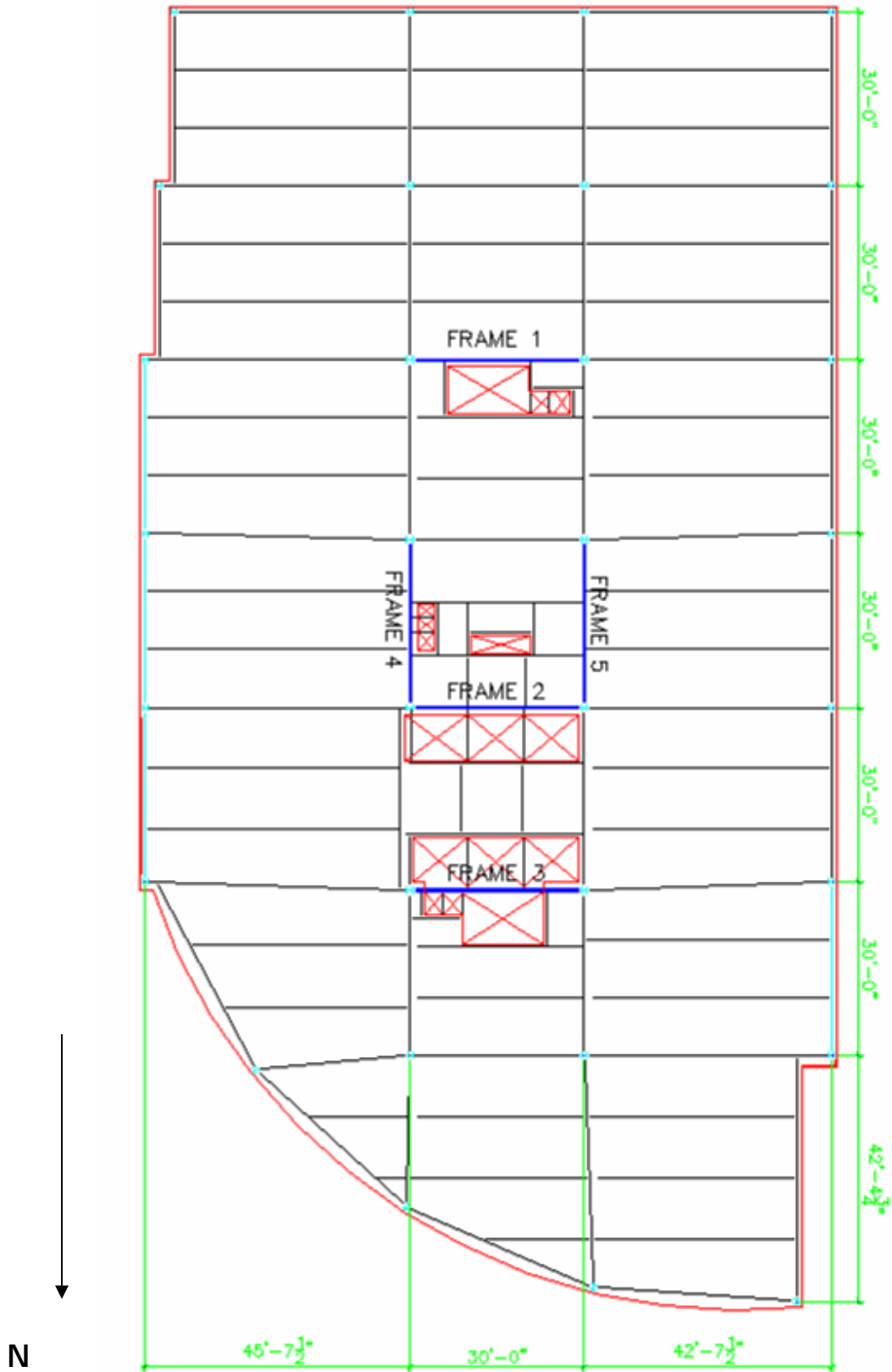
Note: Shaded area is roof construction



11th and 12th Floor Framing Plan



Enlarged Typical Framing Plan with Dimensions



Existing Elevations



Architect: Cooper Carry Architects

The Regent's Southeastern corner and East Elevation looking across Glebe Road



Architect: Cooper Carry Architects

The Regent's Northern Elevation as seen from Glebe Road across North Fairfax Drive

Existing Typical Floor System Design

Levels 2-12 are intended to be used as rentable office space. The loads considered for the existing floor system design were researched, studied, and verified in Technical Report 1: Structural Concepts/Structural Existing Conditions Report, and are summarized below.

Loads:

Dead:

3 ¼" lt. wt. slab on 3" - 20 gage metal deck	46 PSF
Concrete Ponding	10 PSF
Misc. DL	15 PSF
Façade	15 PSF
Construction DL	56 PSF

Live:

Office	100 PSF (reducible)
Construction LL	20 PSF

The existing typical office floor system design consists of a concrete slab on metal deck supported by composite steel beams. The slab is 3 ¼" light weight concrete with an f'c = 3000 psi and is reinforced with 6 x 6 10/10 WWF. The metal deck is 3" – 20 gage composite steel deck bringing the total slab thickness to 6 ¼". The composite action between the slab on metal deck and the steel beams is provided by ¾" diameter, 5" headed shear studs.

There are three typical bay sizes for the steel superstructure above grade; 30' x 30', approximately 46' x 30', and approximately 43' x 30'. From North to South the columns are at a 30' spacing. From East to West the columns spacings are approximately 46', 30' and 43' respectively.

All of the columns are W14's.

The most common beam sizes are W18 x 50 for the 46' x 30' bays, W18 x 46 for the 43' x 30' bays, and W16 x 26 for the 30' x 30' bays with cambers ranging from ¾" to 2" which are designed to 75% dead load. The most common girder sizes are W18 x 65, W24 x 55, W24 x 62, W24 x 55 and W21 x 44 around the perimeter.

Alternative Structural Design Considerations

Four alternative floor system designs were analyzed and designed in Technical Report 2: Pro-Con Structural Study of Alternate Floor Systems. These four alternative floor systems include:

- Hollow-Core Planks with Steel Framing System
- One-way Wide Module Joists, Multiple Spans, with Cast-In-Place Framing System
- Precast Double Tees with Precast Framing System
- Two-way Flat Slab with Drop Panels with Cast-In-Place Framing System

Each alternative floor system design was discussed and their advantages and disadvantages were compared amongst each other and to the existing floor framing system.

A system comparison chart was compiled for and is reproduced from Technical Report 2 below.

System Comparison Chart

System	Pros	Cons	Considerations
Existing Composite Slab on Metal Deck with Composite Steel Beams and Steel Framing	<ul style="list-style-type: none"> • Lighter structure • Quick construction • Smaller foundations • Relatively small depths • Smaller columns sizes • Can efficiently accommodate longer spans 	<ul style="list-style-type: none"> • Concrete ponding over the long spans • Lots of beams 	<ul style="list-style-type: none"> • None at this point
Precast Hollow-Core Planks / Steel Framing	<ul style="list-style-type: none"> • Quick construction • Relatively smaller foundations • Lighter structure • Smaller column sizes • Quality control • Relatively small depths • Less steel beams needed per bay • Good fire rating • Good acoustical value 	<ul style="list-style-type: none"> • Lots of deliveries to a downtown site • Angle detailing to support the planks • Deeper, heavier steel members 	<ul style="list-style-type: none"> • Composite action between the steel beams and the hollow-core planks • Prefabrication of angles to the webs • Adding infill beams to get smaller beam and plank sizes
Precast Double Tees / Precast Framing	<ul style="list-style-type: none"> • Quick construction • Quality control • Good fire resistance • Can accommodate longer spans • Less labor intensive • Less labor costs • Good acoustical value • Double tee self weight comparable to slab on deck weight 	<ul style="list-style-type: none"> • Larger foundations • Deep flooring system • Heavy beams and columns • Lots of deliveries to a downtown site 	<ul style="list-style-type: none"> • Smaller bay sizes • Shallower supporting members (not flush)
CIP One-way Wide Module Joists / CIP Framing	<ul style="list-style-type: none"> • Uniform depth • Rigid floor system • Slab and supporting beam depths are less than existing depths • Can accommodate longer spans • Good fire rating 	<ul style="list-style-type: none"> • Larger foundations • Heavy structure • Labor intensive • Longer construction time • More field labor intensive • Larger column sizes • Forming and shoring system required 	<ul style="list-style-type: none"> • Smaller bay sizes, more columns
CIP Two-way Flat Slab with Drop Panels / CIP Framing	<ul style="list-style-type: none"> • Good fire resistance 	<ul style="list-style-type: none"> • Not practical from a constructability, cost, labor, standpoint for the existing bay sizes • Very heavy structure • Larger foundations • Larger column sizes • Extensive forming and shoring systems required 	<ul style="list-style-type: none"> • Two-way post-tensioning • Smaller bay sizes, more columns

Based off of the initial study, all of the alternative floor systems were selected to be studied further except the Two-way Flat Slab with Drop Panels with Cast-In-Place Framing System for the following reasons:

- Not practical from a constructability, cost, and labor standpoint for the existing bay sizes (minimum slab depth = 16.5", 21" at the drop panels)
- Very heavy structure, significantly heavier than the existing design (≈ 210 PSF vs 56 PSF)
- Would require significantly larger foundations
- Larger column sizes required
- Extensive forming and shoring systems required

The initial design team goals and the original design were then taken into consideration. They are listed below:

- Cost
- Quick construction
- Typical floor to floor height 13' (existing system)
- Typical floor to ceiling height = 9' (existing system)
- Keep existing column layout to keep open floor layout for tenant flexibility
- Lighter structure = lighter foundations = less cost (existing system)
- Maximum height restrictions $\approx 176'$ (existing system)

System	Reasons for Elimination
Precast Double Tees with Precast Framing System	<ul style="list-style-type: none"> • The depth of this system was exactly 4' which is significantly deeper than the existing system, which has a maximum depth of 30.25". This means that the floor to ceiling height would be reduced. (DEPTH)
Precast Hollow-Core Planks / Steel Framing	<ul style="list-style-type: none"> • In order to minimize the depth of the floor system, the planks would require angles connected to the web of the steel beams. Fabrication and detailing of the angles would be very expensive. Also, the size of the beams increased significantly over the existing system due to the loss of composite action between the concrete on deck and the beams. (COST, DEPTH)
One-way Wide Module Joists / CIP Framing	<ul style="list-style-type: none"> • The weight of this system is significantly greater than the existing system. Also, since everything in this system is cast-in-place, this system would take long to erect. However, the depth of this system is comparable to the existing system. (TIME, WEIGHT)

Based off of the previously mentioned initial design team goals and alternative floor system research and analysis, it is determined that the existing structural system is the most efficient design to meet the needs of the building, the project team, the schedule, and the site.

Statement of the Problem

Based off of the study, research, analysis, and designs of the existing system and the four alternative systems, it was determined that the existing system is the most efficient design to meet the needs of the building, the project team, the schedule, and the site. Ideas for a redesign of the existing structure to make it a more efficient structure are difficult to find, if they even exist.

Having studied the existing steel structure all semester, I want to challenge myself next semester by proposing to do a redesign of this building using a concrete system. Although my initial conclusions are that the existing steel design is the most appropriate for this building, I want to do a redesign of The Regent using a concrete system in order to make comparisons between the two systems.

The criteria for the existing design were discussed in the previous section. A concrete system design shall be selected that meets as many of the criteria as possible in order to make a fair comparison between the concrete system and the existing steel system.

Comparisons between the two systems will be based on the following:

- Cost
- Schedule
- Constructibility
- Labor
- Floor to floor height
- Floor to ceiling height
- Lateral system performance (braced frames vs. shearwalls)
- Weight
- Impact on the foundations

Proposed Solution to the Problem

Floor System

In reviewing the results of the alternative floor systems involving concrete design in Technical Report 2, it has been decided to explore the following concrete system in the redesign of The Regent.

- One-way Joists, Wide Module, with all Cast-In-Place Framing

In comparison to the other concrete systems considered, this concrete system is expected to be the lightest in weight and the shallowest in depth.

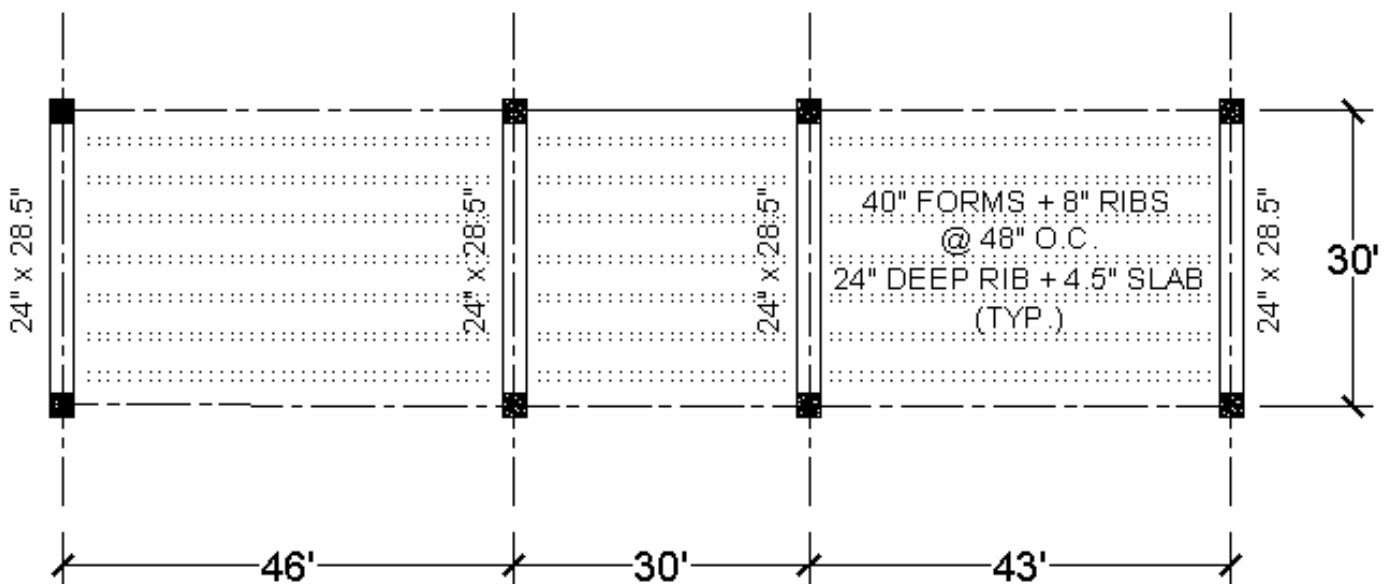
The goal is to keep the same column layout as the existing steel system in order to keep the original design intention of an open floor plan.

One-way Joists, Wide Module, with Cast-In-Place Framing

The One-way Joists with CIP Framing system was preliminarily designed in Technical Report 2 using the CRSI Handbook. The preliminary design is sketched below.

Please refer to CRSI, pages 8-67, 12-93, and 12-107, which can be found in the Appendix, for dimensions, reinforcing details, and properties of members. Also included in the Appendix are the calculations and loads considered for design.

Typical Floor Framing Plan for One-way Wide Module Joists with Cast-In-Place Framing System Design



ALL COLUMNS 24" x 24" MIN.

Joist Selection: 40" Forms + 8" Ribs @ 48" o.c.
 24" Deep Rib + 4.5" Top Slab = 28.5" Total Depth
 $f'_c = 4,000$ psi
 $f_y = 60,000$ psi

End Span: 764 PLF < 873 PLF ∴ OK
 Top Bars: #7 @ 9"
 Bottom Bars: 1 - #10 and 1-#10
 Stirrups: #3 @ 13" for 204"

Interior Span: 764 PLF < 926 PLF ∴ OK

Top Bars: #6 @ 7"

Bottom Bars: 1 - #8 and 1-#9

Stirrups: #3 @ 13" for 167"

Interior Beam Selection:

24" x 28.5"

Top: (5) #14

Bottom: (2) #14

Stirrups (Closed): (16) #5, 1@2", 25@7"

12.5 PLF > 10.83 PLF ∴ **OK**

Exterior Beam Selection:

24" x 28.5"

Top: (4) #14

Bottom: (2) #14

Stirrups (Closed): (23) #5, 1@2", 22@8"

10.1 PLF > 6.9 PSF ∴ **OK**

Lateral Force Resisting System

The existing structure utilizes a series of 5 braced frames; 2 spanning in the north / south direction and 2 spanning in the east / west direction. Since the redesign will be an all concrete system, a series of concrete shearwalls will be used as the lateral force resisting system. These shearwalls will ideally be placed around the elevator core and/or around the stairwells. Both the elevators and the stairwells are located in the central core of the building.

Loads

The loads considered for the existing design of The Regent were research, analyzed and checked throughout all of the Technical Reports. In some cases, the loads determined corresponded to the loads used in the existing design, in other cases they did not. In reviewing the loads considered for the existing design, some of the loads seemed to be very conservative such as the floor live load and the snow load, 100 PSF and 30 PSF, respectively. These conservative loadings may have been minimum requirements set forth by the structural engineer on this project. In the concrete redesign of The Regent, the loads considered will be optimized and will be based off of IBC 2000, which was the model code used in the existing design. Although a direct comparison cannot be completed between the existing design and the redesign, the optimized loads will yield a more efficient design for the new concrete design.

Solution Method

The design of the concrete structure will be based off of ACI 318-05: *Building Code Requirements for Structural Concrete*. Analysis for gravity loads will be completed by hand calculations and/or through the use of structural analysis and design software: ADOSS, SAP, and PCACOL. Analysis of lateral loads will be completed using SAP2000. Trial sizes based off of the preliminary designs, determined through the CRSI Handbook and hand calculations, will be inputted into the computer programs along with the newly determined, optimized gravity and lateral loads. Live loading patterns will be considered and used to properly design the concrete gravity system.

Scope of Structure to be Designed

- Floor System - One-way Joists, Wide Module
- Cast-In-Place Beams
- Cast-In-Place Columns
- Lateral Load Resisting Shearwalls
- Foundations

Breadth Analyses

Construction Management

Since two of the key factors in selecting the existing structural system were cost and speed of erection, a construction management breadth analysis will be conducted to estimate the cost and scheduling differences between the existing system and the new concrete system. Since it already has been initially pre-determined that the existing system is the most cost effective and the quickest to erect, the cost and schedule comparison will be used to determine approximately how much time and money was saved by going with the steel system, if the initial assumption was correct.

Mechanical

Since the new concrete system will most likely have a new depth and framing layout, the mechanical system sizes and layout may not be compatible with the new spatial requirements and layout of the new concrete system. The impact on the mechanical system layout will be analyzed, and if there are conflicts with space and layout between the new concrete structure and the existing mechanical system, a new mechanical system layout will be proposed.

Fire Protection

Since the new concrete structure is a new material, layout, and thickness than the existing steel structure, it will have a different fire rating. The fire rating of the new concrete system will be compared with the fire rating of the existing steel system. Also, any impacts on cost by utilizing the concrete system will be determined.

Acoustics

Since the new concrete system is significantly different than the existing steel system, it will have different acoustical values and effects. The Regent is primarily a spec office building, which has the potential to have several different tenants. An acoustical study will be performed on each system to see which performs better in preventing noise from penetrating through the floor system.

Tasks and Tools

Cast-In-Place Concrete Redesign

Task 1: Establish Trial Floor Plan and Member Sizes

- Determine preliminary floor plan (keeping existing column locations, determine joist span, shearwall locations, column and beam placement, coordinate with architectural drawings, etc.).
- Determine slab, joist, and beam limitations based off of ceiling height requirements and floor to floor height requirements.
- Determine economical balance between beam and floor system thickness.
- Determine trial pan size and depth and joist stem width and slab thickness.
- Determine of trial beam and column sizes using CRSI Handbook and ACI 318-05.

Task 2: Determine Optimized Loads, Gravity and Lateral

- Based on the IBC 2000, determine code required lateral and gravity loads and revise previously determined loads used in the Technical Reports.
- Determine the superimposed dead loads based off of building plans.
- Determine the live loads based off of IBC 2000 Table 1607.1.
- Determine the roof live load and snow load based off of ASCE 7-02, Chapters 4 and 7, respectively.
- Determine the wind loads based off of ASCE 7-02, Chapter 6, Method 2: Analytical Procedure.
- Determine seismic loads based off of ASCE 7-02, Chapter 9.
- Determine the self weight of trial members.
- Make a comparison chart of existing design loads and optimized design loads.
- Determine construction live loads and dead loads.

Task 3: Complete Initial Structural Analysis of Floor Framing System

- Determine factored shear and moment requirements and deflection limits in a typical bay based off of the newly determined loads.
- Check initial joist and beam size members by calculating joist and beam capacities based off of ACI 318-05 and compare to factored shear and moments.

Task 4: Complete Initial Structural Analysis of Shearwalls

- Complete initial lateral analysis of shearwalls by inputting initial shearwall sizes and locations and lateral loads into SAP2000 and run analysis
- Check computer results with hand calculations.

Task 5: Revise Trial Members based off of Initial Analysis

- Revise trial joist and beam sizes based off of initial analysis (repeat until system design is adequate to carry the applied gravity loads).
- Revise trial shearwall sizes based off of the initial computer analysis (repeat until system design is adequate to resist the applied lateral loads).
- Check results with hand calculated spot checks.

Task 6: Determine Column Loadings

- Determine column loadings throughout the structure.

Task 7: Complete Column Analysis and Design

- Use PCACOL to check the adequacy of the trial column sizes and design the columns for the determined loadings.
- Check PCACOL results with hand calculated spot checks.

Task 8: Complete a 3-D Structural Model of the Entire Building Using SAP2000

- Run an analysis of the structure as designed to this point for gravity and lateral loads.
- Revise any members that are not adequate.

Task 9: Preliminarily Redesign Foundations Based off of New Concrete Design and Loads

Task 10: Complete Construction Management Breath Study

- Complete cost analysis of the existing steel system and the new concrete system.
- Complete a schedule analysis of the existing steel system and the new concrete system.

Task 11: Other Breadth Studies: Mechanical, Fire Protection, Acoustical

- Determine the effects on the mechanical system layout due to the change in floor structure.
- The effect of the new structure with respect to spatial requirements.
- Determine the fire rating differences between the existing steel system and the new concrete system.
- Determine the acoustical differences between the existing steel floor system and the new proposed concrete floor system.

Task 12: Prepare Report

Task 13: Prepare Presentation

Schedule

Week	Week of	Work Description
1	01/09/06	Establish Trial Floor Plan and Member Sizes (started in Technical Report 2) Determine Optimized Loads, Gravity and Lateral
2	01/16/06	Complete Initial Structural Analysis of Floor Framing System Complete Initial Structural Analysis of Shearwalls
3	01/23/06	Revise Trial Members Based off of Initial Analyses
4	01/30/06	Determine Column Loadings Complete Column Analysis and Design
5	02/06/06	Start a 3-D Structural Model using SAP 2000
6	02/13/06	Finish 3-D Model, Run Analysis, Perform Any Redesigns
7	02/20/06	Preliminary Redesign of Foundations Considering New Concrete Structure Design and Loadings
8	02/27/06	Complete Construction Management Breath Study
9	03/06/06	SPRING BREAK
10	03/13/06	Complete Other Breadth Studies: Mechanical, Fire Protection, Acoustical
11	03/20/06	Type Report
12	03/27/06	Type Report Edit Report Start Presentation
13	04/03/06 04/05/06	Print and Bind Report Final Report Due Finish Presentation Edit Presentation
14	04/10/06 04/11/06 04/12/06	Presentations Presentations Presentations

Conclusion

The Regent is located at 950 North Glebe Road in Arlington, Virginia. The building is a 12-story spec office building with retail space on the first level. There is also a 3-story parking garage below grade. The building is designed to a maximum allowable height of 176 feet. The Regent is currently under construction, and since the building was not pre-leased before construction began, the occupants or tenants are not known at this point.

Based off of the study, research, analysis, and designs of the existing system (steel framing with composite slab) and the four alternative systems (hollowcore planks with steel framing, precast double tees with precast framing, one-way wide module joists with CIP framing, and a two-way flat slab with drop panels and CIP framing), it was

determined that the existing system is the most efficient design to meet the needs of the building, the project team, the schedule, and the site.

Having studied the existing steel structure all semester, I wanted to challenge myself next semester by proposing to do a redesign of this building using a concrete system. Although my initial conclusions are that the existing steel design is the most appropriate for this building, I want to do a redesign of The Regent using a concrete system in order to make comparisons between the two systems.

A concrete system design shall be selected that meets as many of the initial design team's criteria as possible in order to make a fair comparison between the concrete system and the existing steel system.

Comparisons between the two systems will be based on the following:

- Cost
- Schedule
- Constructibility
- Labor
- Floor to floor height
- Floor to ceiling height
- Lateral system performance (braced frames vs. shearwalls)
- Weight
- Impact on the foundations

In reviewing the results of the alternative floor systems involving concrete design in Technical Report 2, it has been decided to explore the following concrete system in the redesign of The Regent.

- One-way Joists, Wide Module, with all Cast-In-Place Framing

In comparison to the other concrete systems considered, this concrete system is expected to be the lightest in weight and the shallowest in depth. Another goal is to keep the same column layout as the existing steel system in order to keep the original design intention of an open floor plan.

The existing structure utilizes a series of 5 braced frames; 2 spanning in the north / south direction and 2 spanning in the east / west direction. Since the redesign will be an all concrete system, a series of concrete shearwalls will be used as the lateral force resisting system. These shearwalls will ideally be placed around the elevator core and/or around the stairwells. Both the elevators and the stairwells are located in the central core of the building.

The loads considered for the existing design of The Regent were research, analyzed and checked throughout all of the Technical Reports. In some cases, the loads determined corresponded to the loads used in the existing design, in other cases they

did not. In reviewing the loads considered for the existing design, some of the loads seemed to be very conservative such as the floor live load and the snow load, 100 PSF and 30 PSF, respectively. These conservative loadings may have been minimum requirements set forth by the structural engineer on this project. In the concrete redesign of The Regent, the loads considered will be optimized and will be based off of IBC 2000, which was the model code used in the existing design. Although a direct comparison cannot be completed between the existing design and the redesign, the optimized loads will yield a more efficient design for the new concrete design.

The design of the concrete structure will be based off of ACI 318-05: *Building Code Requirements for Structural Concrete*. Analysis for gravity loads will be completed by hand calculations and/or through the use of structural analysis and design software: ADOSS, SAP, and PCACOL. Analysis of lateral loads will be completed using SAP2000. Trial sizes based off of the preliminary designs, determined through the CRSI Handbook and hand calculations, will be inputted into the computer programs along with the newly determined, optimized gravity and lateral loads. Live loading patterns will be considered and used to properly design the concrete gravity system. Scope of Structure to be Designed

- Floor System - One-way Joists, Wide Module
- Cast-In-Place Beams
- Cast-In-Place Columns
- Lateral Load Resisting Shearwalls
- Foundations

As part of the breadth analysis requirements, the following breadth areas have been chosen to be studied in order to help compare the two systems.

- Construction Management
 - Cost
 - Schedule
- Mechanical
 - Impact on mechanical layout
 - Possible redesign of mechanical layout if necessary
- Fire Protection
 - Comparison in fire rating between the existing steel floor system and the new concrete floor system
- Acoustics
 - Comparison between the resistance to noise penetrations between the existing steel floor system and the new concrete floor system.

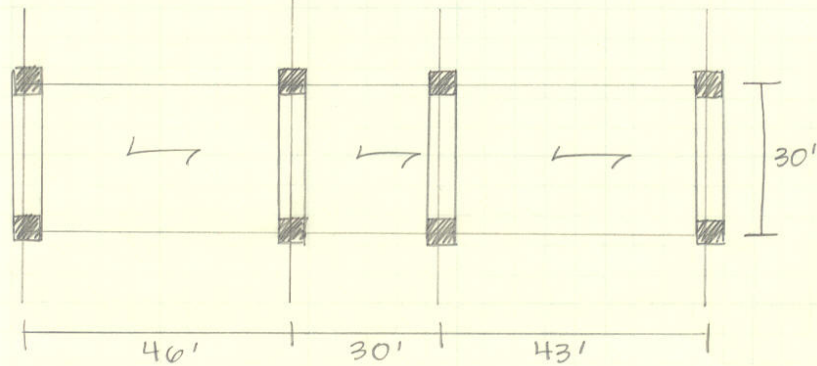
A schedule has been prepared describing what tasks will be completed and when throughout the semester.

Appendix

**Wide Module One-Way Joists, Multiple Spans
with CIP Framing System**

Wide Module one-way Joists, Multiple Spans

Joists Spanning Long Direction



worst case span = 40'

Loads:

Dead Load

Misc. DL = 15 PSF

Live Load

Office = 100 PSF

$A_t = 4'(40') = 164 \text{ Ft}^2$
 $< 400 \text{ Ft}^2$
 \therefore Not Reducible

Factored Superimposed Load

$$1.4(15 \text{ PSF}) + 1.7(100 \text{ PSF}) = 191 \text{ PSF}$$

Use $1.4D + 1.7L$ in order to use CRSI charts

$$191 \text{ PSF}(4') = 764 \text{ PLF}$$

Wide Module One-Way Joists Spanning the Long Direction

Possible Joist Systems Take from CRSI

Option	Form Widths (IN)	Rib Widths (IN)	C-C Width (IN)	Rib Depth (IN)	Slab Depth (IN)	End Span Capacity (PLF)	Interior Span Capacity (PLF)	Self Weight (PLF)
1	40	8	48	24	4.5	873	926	475
2	40	9	49	24	4.5	987	1066	505
3	40	10	50	24	4.5	791	844	534
4	53	8	61	24	4.5	794	845	536
5	53	9	62	24	4.5	908	985	566
6	53	10	63	24	4.5	883	1110	595
7	66	9	75	24	4.5	827	903	627

Selection: 40" Forms + 8" Ribs @ 48" o.c.
 24" Deep Rib + 4.5 "Top Slab = 28.5" Total Depth
 $f'_c = 4,000$ psi
 $f_y = 60,000$ psi

End Span: **764 PLF < 873 PLF ∴ OK**

Top Bars: #7 @ 9"
 Bottom Bars: 1 - #10 and 1-#10
 Stirrups: #3 @ 13" for 204"

Interior Span: **764 PLF < 926 PLF ∴ OK**

Top Bars: #6 @ 7"
 Bottom Bars: 1 - #8 and 1-#9
 Stirrups: #3 @ 13" for 167"

This wide-module one-way joist system was selected because it was the lightest design and because it had a modular width of exactly 4'. All of the possible systems had the same total depth.

Interior Beam Selection:

24" x 28.5"
 Top: (5) #14
 Bottom: (2) #14
 Stirrups (Closed): (16) #5, 1@2", 25@7"
 12.5 PLF > 10.83 PLF ∴ **OK**

Exterior Beam Selection:

24" x 28.5"
 Top: (4) #14
 Bottom: (2) #14
 Stirrups (Closed): (23) #5, 1@2", 22@8"
 10.1 PLF > 6.9 PSF ∴ **OK**

Interior Joist Band Beams

max. span = 30'

Loads:

Dead:

Misc. DL = 15 PSF
Joists = 119 PSF

Live:

Office = 100 PSF \rightarrow 57 PSF

$$W_u = 1.4(15 + 119) + 1.7(57) \\ = 285 \text{ PSF}$$

$$W_u = 285 \text{ PSF} \left(\frac{46' + 30'}{2} \right) \\ = 10,830 \text{ PLF} \\ = 10.83 \text{ KLF}$$

$d = 28.5'$ to match total joist depth

Live Load Reduction

$$A_T = 38'(30') = 1140 \text{ FT}^2$$

$$K_{LL} = 2$$

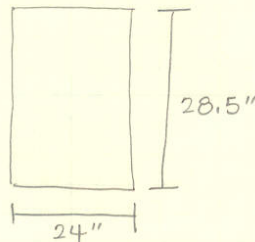
$$L_o = 100 \text{ PSF}$$

$$L = 100 \left(0.25 + \frac{15}{\sqrt{2 \cdot 1140}} \right)$$

$$L = 57 \text{ PSF}$$

Selection:

$f'_c = 4000 \text{ psi}$
 $f_y = 60,000 \text{ psi}$



span = 30'

Bottom Bars:

$$l_n + 12'' = (2) \# 14$$

$$0.875 l_n = (1) \# 14$$

Top Bars: (5) # 14

load capacity = 12.5 K/FT $>$ 10.83 K/FT \therefore OK

Stirrups: 2#5 E closed stirrups

$$2\phi - \#5: 1 @ 2''$$

$$25 @ 7''$$

Exterior Joist Band Beams

max. span = 30'

Loads:

Dead:

Misc. DL = 15 PSF

Joists = 119 PSF

Live:

Office = 100 PSF \rightarrow 66 PSF

Live Load Reduction

$A_T = 23'(30') = 690 \text{ FT}^2$

$K_{LL} = 2$

$L_o = 100 \text{ PSF}$

$$L = 100 \left(0.25 + \frac{15}{\sqrt{2 \cdot 690}} \right)$$

$L = 66 \text{ PSF}$

$$W_u = 1.4(15 + 119) + 1.7(66)$$

$$= 300 \text{ PSF}$$

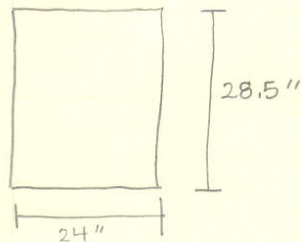
$$W_u = 300 \text{ PSF} \left(\frac{46'}{2} \right)$$

$$= 6900 \text{ PLF}$$

$$= 6.9 \text{ KLF}$$

Selection

$f'_c = 4000 \text{ psi}$
 $f_y = 60,000 \text{ psi}$



Span =

Bottom Bars:

$d_n + 12'' = 2 \#14$

$0.875d_n = 2 \#14$

Top Bars: (4) #14

Stirrups: 235 F

- closed stirrups

- 23 #5; 1 @ 2"

22 @ 8"

Load capacity: $10.1 \text{ K/FT} > 6.9 \text{ K/FT}$

WIDE MODULE (1)		40" Forms + 9" Ribs @ 49" c.-c.										f _c = 4,000 psi f _y = 60,000 psi		
ONE-WAY JOISTS		24" Deep Rib + 4.5" Top Slab = 28.5" Total Depth										FACTORED USABLE SUPERIMPOSED LOAD (PLF)		
MULTIPLE SPANS		FACTORED USABLE SUPERIMPOSED LOAD (PLF)										Span		
TOP BARS	NO	#5	#6	#6	#7	#7	#8	#8	#9	#9	#9	#9	Int.	
BOTTOM BARS	NO	2#4	1#6	2#7	1#8	1#8	1#8	2#8	2#8	2#8	2#8	2#8	Span	
BARS	NO	2#5	2#7	1#8	1#8	1#8	2#9	2#9	2#9	2#9	2#9	2#9	Defl.	
STEEL	(PSF)	1.02	1.61	2.01	2.37	2.78	(2)	(2)	(2)	(2)	(2)	(2)	Coef.	
CLEAR SPAN		END SPAN										INTERIOR SPAN		
37'-0" (3)	271	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
38'-0"	221	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
39'-0"	174	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
40'-0"	130	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
41'-0"	90	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
42'-0"	52	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
43'-0"	37	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
44'-0"	21	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
45'-0"	15	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
46'-0"	10	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
47'-0"	6	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
48'-0"	3	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101
49'-0"	1	#3-59	#3-133	#3-154	#3-155	#4-185	1911	1527	1911	716	1560	2033	2543	3101

WIDE MODULE (1)		40" Forms + 8" Ribs @ 48" c.-c.										f _c = 4,000 psi f _y = 60,000 psi		
ONE-WAY JOISTS		24" Deep Rib + 4.5" Top Slab = 28.5" Total Depth										FACTORED USABLE SUPERIMPOSED LOAD (PLF)		
MULTIPLE SPANS		FACTORED USABLE SUPERIMPOSED LOAD (PLF)										Span		
TOP BARS	NO	#4	#5	#6	#6	#7	#7	#8	#8	#8	#8	#8	Int.	
BOTTOM BARS	NO	2#5	1#8	1#8	1#8	1#8	1#8	1#8	1#8	1#8	1#8	1#8	Span	
BARS	NO	1#5	1#8	1#9	2#8	1#9	2#8	1#10	1#10	1#10	1#10	1#10	Defl.	
STEEL	(PSF)	.92	1.64	1.85	2.19	2.70	(2)	(2)	(2)	(2)	(2)	(2)	Coef.	
CLEAR SPAN		END SPAN										INTERIOR SPAN		
37'-0" (3)	226	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
38'-0"	180	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
39'-0"	137	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
40'-0"	97	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
41'-0"	61	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
42'-0"	49	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
43'-0"	33	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
44'-0"	21	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
45'-0"	14	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
46'-0"	9	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
47'-0"	6	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
48'-0"	4	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794
49'-0"	3	#3-59	#3-138	#3-153	#3-153	#4-185	1713	1332	1713	631	1512	1795	2293	2794

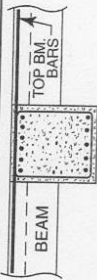
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(1) For gross section properties, see Table 8.3.
 (2) Computation of deflection is not required above horizontal line (thickness $\geq \ell_r/18.5$ for end spans, $\ell_r/21$ for interior spans).
 (3) Single leg stirrup size space at X in. c.-c. Distance over which stirrups must extend from face of support at each end (in.).

(1) For gross section properties, see Table 8.3.
 (2) Computation of deflection is not required above horizontal line (thickness $\geq \ell_r/18.5$ for end spans, $\ell_r/21$ for interior spans).
 (3) Single leg stirrup size space at X in. c.-c. Distance over which stirrups must extend from face of support at each end (in.).

**JOIST-BAND BEAMS,
INTERIOR SPANS**

$f'_c = 4,000$ psi
 $f_y = 60,000$ psi



STEM	BARS ⁽¹⁾		TOTAL CAPACITY $U = 1.4D + 1.7L^{(3)}$												DEFL (C)							
	h in.	b in.	Bottom	Top	SPAN, $l_n = 30$ ft			SPAN, $l_n = 34$ ft			SPAN, $l_n = 36$ ft			(6)		(7)						
			Layers	Layers	LOAD (4)	STIR TIES (5)	STEEL WGT lb.	LOAD (4)	STIR TIES (5)	STEEL WGT lb.	LOAD (4)	STIR TIES (5)	STEEL WGT lb.	LOAD (4)	STIR TIES (5)	STEEL WGT lb.	LOAD (4)	STIR TIES (5)	STEEL WGT lb.	(ft-kip)	($\times 10^{-9}$ in.)	
			1	1	6.7	113J	23	814	5.9	123J	23	870	23	917	4.7	123J	23	963	4.7	123J	23	122
			1	1	8.1	175I	93	1331	7.1	195H	92	1451	91	1571	5.6	225H	91	1655	5.6	225H	91	121
			1	1	12.5	235F	93	1718	11.0	245F	92	1812	91	1876	8.7	164J	91	1988	8.7	164J	91	96
			1	1	15.4	265E	93	2365	13.5	285E	92	2532	91	2551	10.7	165J	91	2681	10.7	165J	91	83
			1	1	10.0	113J	43	1109	8.8	123J	42	1185	42	1251	6.9	123J	42	1316	6.9	123J	42	83
			1	1	12.1	124J	43	1578	10.6	133J	42	1660	42	1737	8.4	133J	42	1838	8.4	133J	42	78
			1	1	16.9	135J	43	2310	14.8	145J	42	2467	42	2624	11.7	154J	41	2886	11.7	154J	41	67
			1	1	20.6	155G	43	3136	18.1	165G	42	3344	42	3552	14.3	165G	41	3744	14.3	165G	41	60
			1	1	12.4	114J	64	1573	10.9	114J	63	1661	63	1748	8.6	124J	62	1858	8.6	124J	62	58
			1	1	17.2	125J	64	2192	15.1	134J	63	2277	63	2394	11.9	144J	62	2533	11.9	144J	62	60
			1	1	24.4	155FJ	64	3167	21.5	165G	63	3304	63	3511	17.0	165G	62	3683	17.0	165G	62	49
			1	1	28.7	205DJ	64	3860	25.2	185FJ	63	3988	63	4196	19.9	185FJ	62	4404	19.9	185FJ	62	44

(1) See "Recommended Bar Details", Fig. 12-1. For girders, use tabulated beam depth — 2 inches ($b - 2"$).

(2) In "Layers" column, first line is number of layers for bottom bars, second line is for number of layers for top bars.

(3) For superimposed factored load capacity, deduct 1.4 x stem weight.

(4) Total capacities tabulated causing deflection in excess of $l_n/360$ are designated thus: * — $l_n/360 < \text{deflection} < l_n/240$; X — $l_n/240 < \text{deflection} < l_n/180$; Y — deflection $> l_n/180$.

(5) For each beam design, first line is for open stirrups, second line is for closed ties. See Fig. 12-4. At free ends, use stirrups tabulated for "Interior Spans". For $b > 24$ in., provide 4 legs (two stirrups) of size and spacing tabulated. For stirrup nomenclature, see page 12-13.

Other notation: N/A — STIRRUPS ARE NOT REQUIRED
** — MAXIMUM SPACING IS LESS THAN 3 INCHES. NOT RECOMMENDED
*** — SHEAR STRESS IS GREATER THAN $10\sqrt{f'_c}$
**** — TORSION STRESS EXCEEDS ALLOWABLE

(6) $+\phi M_n$ and $-\phi M_n$ are design moment strength capacities for rectangular section $D \times h$.

(7) Midspan elastic deflection (in.) = $C \times (w/16) \times l_n^4$, where w = tabulated load (k/ft), l_n in ft.
"Average service load" is taken as $w/1.6$.