

440 FIRST STREET, NW  
WASHINGTON, D.C.



THESIS PROPOSAL

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11 DECEMBER 2015

## EXECUTIVE SUMMARY

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440 First Street is a mixed use building located in Washington, D.C. The existing 8-story building, constructed in the early 80's began renovation in 2012 and was completed in 2013. Three stories were added to the building, including a penthouse, resulting in a 20.6 foot increase in building height and a total gross square footage of about 142000 GSF. The new 10-story architectural design provided a seamless transformation of the existing building into a more modern, state-of-the-art building, well on its way to a platinum LEED certification.

This proposal will include a redesign of the entire structural system using a composite steel joist frame. This new structural system will be modeled and analyzed using RAM, as well as other computer modeling software and design aids.

A construction management breadth, which includes a cost analysis and impact on construction schedule will be analyzed for the new system and compared to the existing. Likewise, a mechanical breath will be studied, with the focus of determining the changes required to the MEP systems due to the change in the structural system.

## TABLE OF CONTENTS

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Executive Summary.....	Page 1
Introduction.....	Page 3
Structural Design.....	Page 4
Overview of Structural System.....	Page 4
Existing Framing.....	Page 5
Floor System.....	Page 6
Roof System.....	Page 8
Typical Bay .....	Page 10
Columns.....	Page 11
Lateral System.....	Page 13
Foundation System.....	Page 15
Joint Detailing.....	Page 16
Building Design Codes and Standards.....	Page 18
Design Loads.....	Page 19
Proposal.....	Page 21
Breadth Topics.....	Page 22
Research/Analysis & Tasks.....	Page 23
Schedule.....	Page 25
Conclusion.....	Page 26
Appendix	

## Introduction

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### Purpose

The purpose of this report is to outline and describe the structural system and other design concepts behind it. The report includes an in-depth look into the structural systems used, specifically the gravity and lateral systems. Furthermore, there will be a description of the codes used in 440 First Street.

### General Description

First Potomac (FP) 440 First Street, NW, as seen in Figure 1, is located between D and E streets in downtown Washington, DC near the United States Capitol. The existing building was originally an 8-story building constructed in 1982 and had no major upgrades until the renovation began in 2012. The renovation comprised of adding three floors, an additional 34,500 SF, which resulted in a 32% increase in floor space over the existing 106,850 GSF. The building height was raised 20'-8" and two floors as the existing roof (story height = 11'-8") was removed through the use of Transfer Development Rights, thus allowing three 10'-9" stories within a total of 32'-3". The renovated building comprises of 10 stories above grade, which includes a penthouse level and 2 stories below grade.



Figure 1 | View from adjacent building

440 First Street is an office/retail building that has been re-constructed to fit the modern day requirements, while remaining aesthetically appealing.

### **Structural Design**

This section offers a broad description of the overall structural design, including an in-depth look into the design criteria and the structural systems proposed for the renovation and addition.

### **Overview of the Structural System**

#### **Building Materials**

The following ASTM standards and design stresses shall be used for the appropriate materials used in the construction of this project.

<b>STRUCTURAL STEEL</b>		
Member	Grade	Fy
Rolled Shapes	ASTM A992, Grade 50	50
Channels, Angles and Plates	ASTM A36	36
Structural Tubing	ASTM A500, Grade B	46
High Strength Bolts	ASTM A325-N	-
Expansion Anchors	HILTI KWIK Bolt TZ	-

<b>MASONRY</b>		
Use	Grade	Strength (PSI)
Load Bearing Concrete ( Hollow and Solid)	ASTM C90	1900
Load Bearing Concrete (Brick)	ASTM C55	2000
Mortar	ASTM C270	-
Grout	ASTM C476	2000
Horizontal Joint Reinforcing	ASTM A82	-
Compressive Strength of Masonry	-	F'm = 1500 PSI

<b>CONCRETE AND REINFORCING</b>		
Use	Weight	Strength (PSI)
Slabs-on-grade (Interior)	145	3000
Slabs-on-grade(Exterior)	145	4500
Fill on metal deck	115	3500
Topping	145	3000
<b>REINFORCEMENT</b>		
Use	Grade	
Deformed Reinforcing Bars	ASTM A615, Grade 60	
Welded Wire Fabric (WWF)	ASTM A185	

## EXISTING FRAMING

The existing building is a cast-in-place concrete structure consisting of two-way structural concrete slabs and reinforced concrete columns and edge beams. A concrete slab on grade is used at the lowest level of the garage. Furthermore, concrete columns and foundation walls are supported by spread footings.

### Existing slab, garage and framing renovations

The existing roof slab and penthouse were removed and the existing slab edges were added to on all four sides for two reasons: increasing the net rentable space for each floor, and to provide a consistent location for new façade connections, as seen in Figure 2. Also, at the front of the building, slab edge and curtain wall at the corner column bays were extended to the property line, requiring cantilevered channel sections which were through bolted to the existing concrete columns, and support a new composite concrete slab.

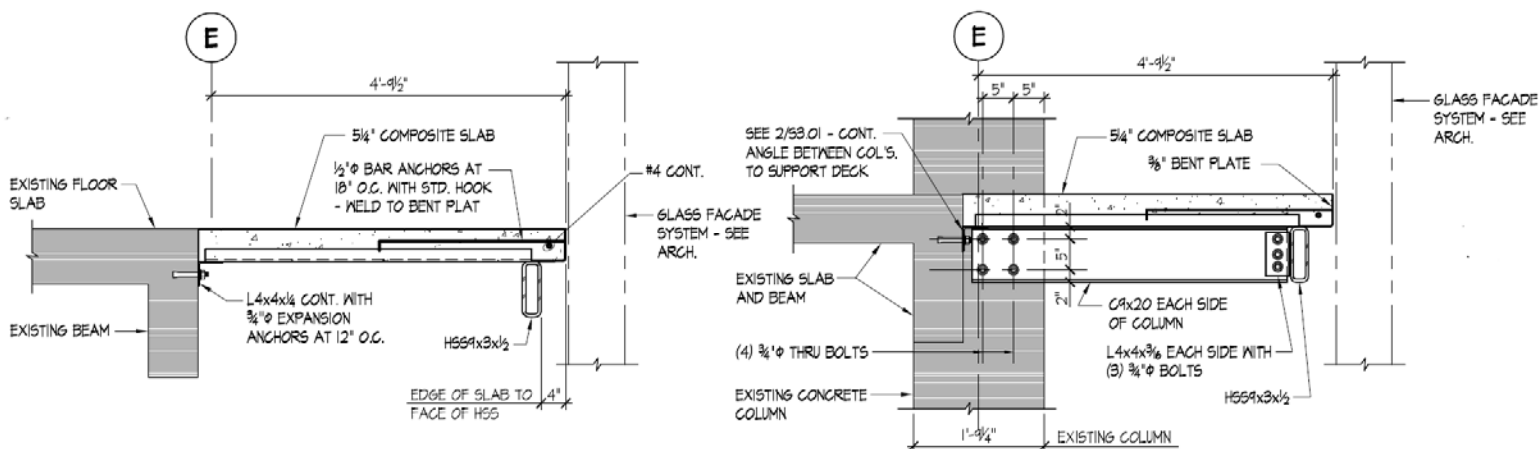


Figure 2 / Slab Extension Details

Slab extension at floors 2 through 8 will occur at the east side of the building toward the north, to match the new upper floors.

The existing garage levels had experienced serious deterioration due to road salts brought in on cars, and the design drawings contained repair plans and details. This work was performed first, and allowed parking for workers of all trades as the construction progressed.



## Floor System

As aforementioned, the floor system is comprised of steel reinforced cast-in-place concrete two-way slab system on typical floors (2-8). It consists of 5 ¼" lightweight concrete on a 2", 18 gage galvanized composite metal deck (total thickness = 7") reinforced with 6x6-W2.9xW2.9 WWF on typical floors, unless noted otherwise. Other slab thickness vary from 5 ¼" – 9 ½", as seen in Figure 3, depending on the location.

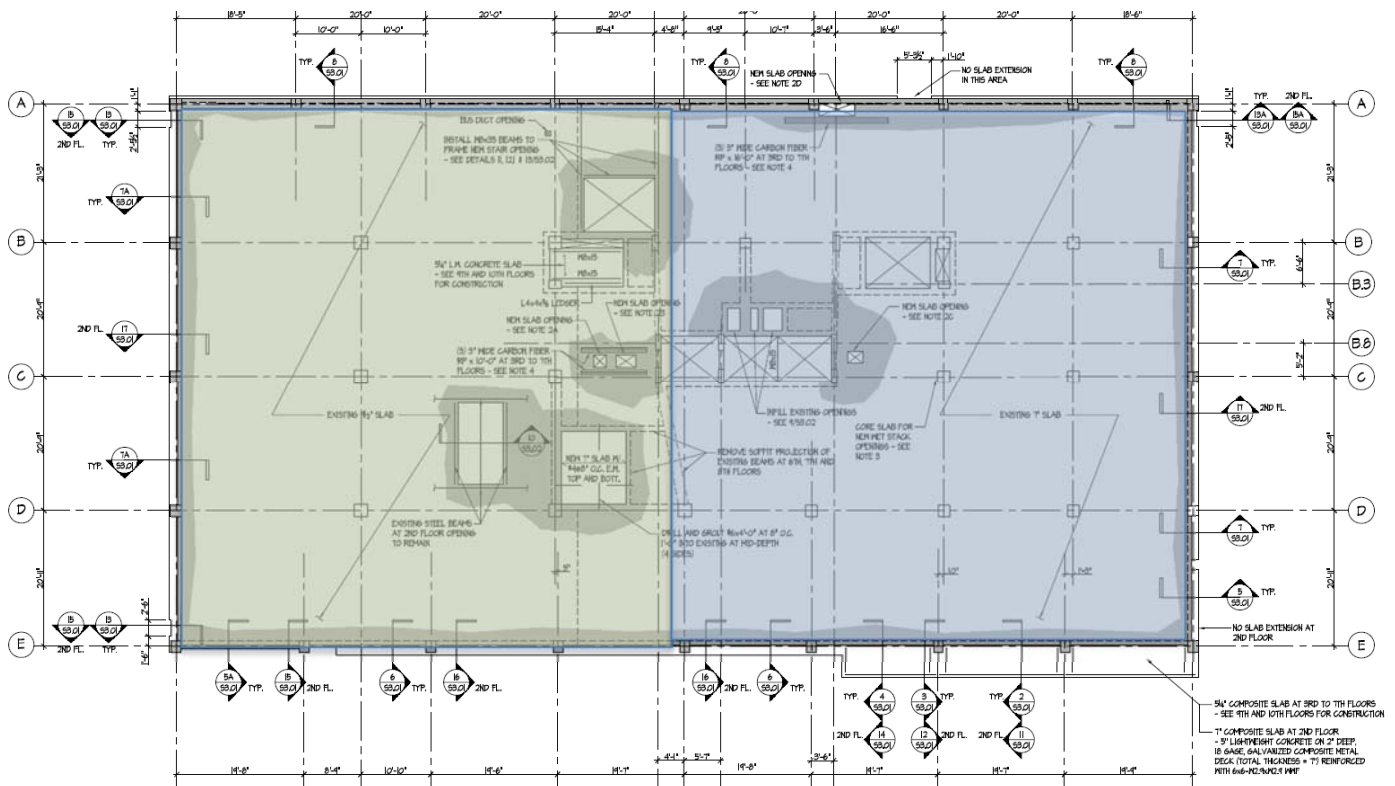
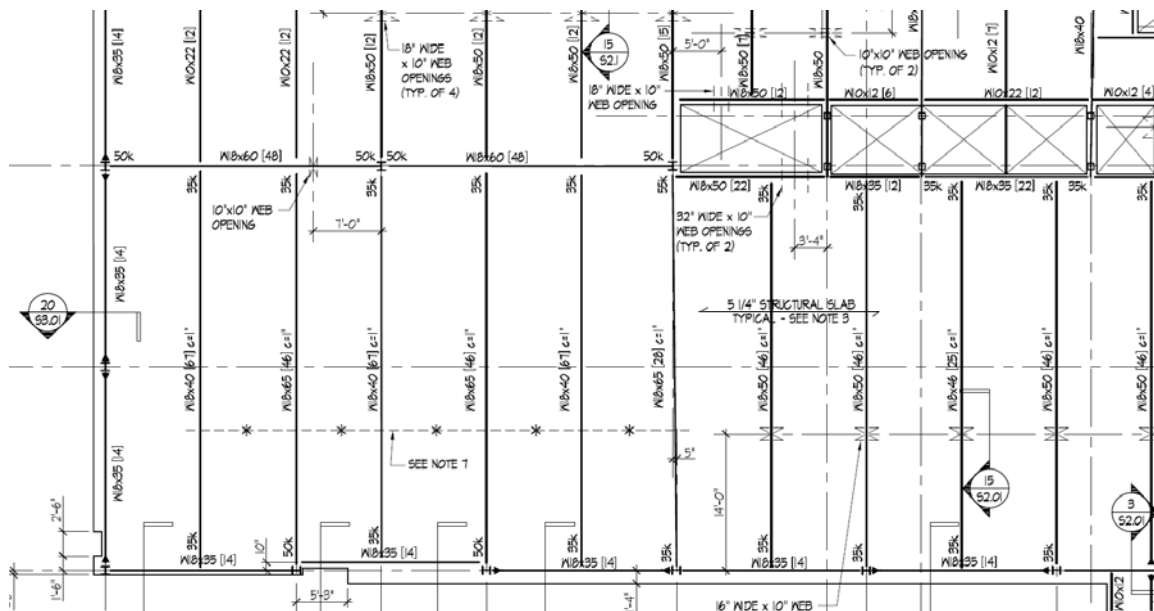
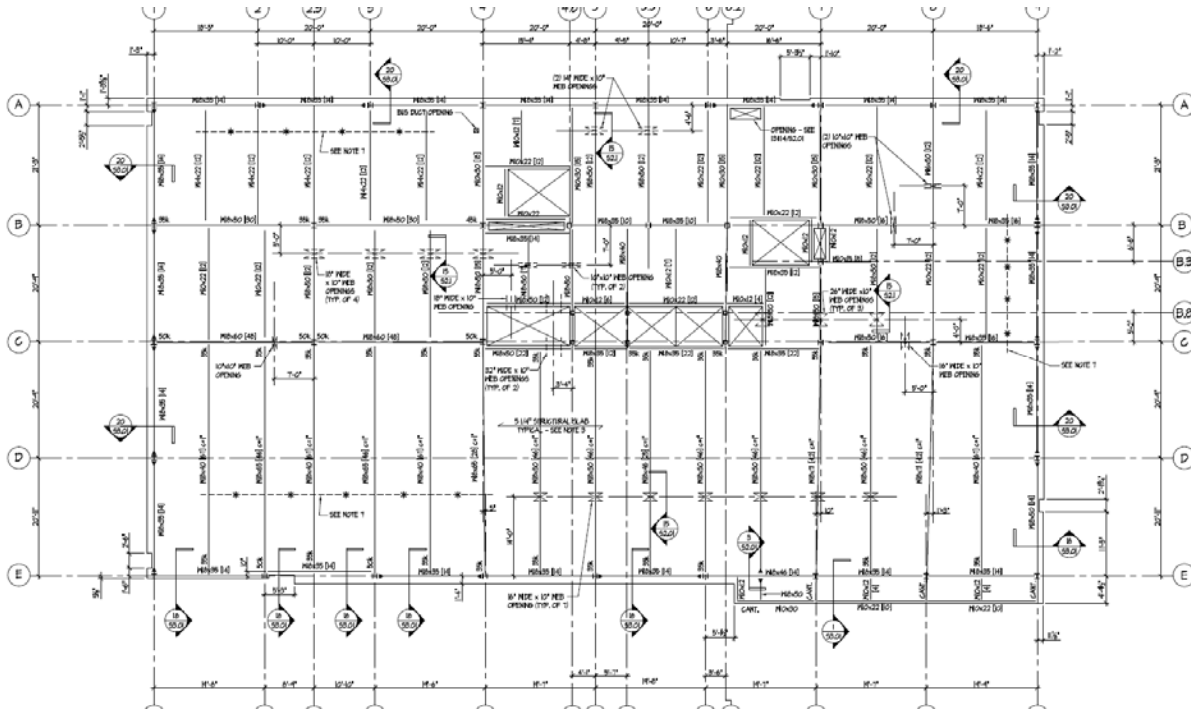


Figure 3 / Typical floor plan of the building

■ 9 ½" slab      ■ 7" slab

## Addition Framing System Overview

There is an addition of three stories of steel framing (two new floors and a roof/penthouse) above the existing 8<sup>th</sup> floor. The new framed floors and roof are constructed using composite framing with a 5 ¼" thick structural slab (comprised of 3 ¼" of lightweight concrete fill on a 2" thick, 18 gage metal deck), reinforced with 6x6-W2.0xW2.0 WWF. Figures 4 and 5 show a typical and partial structural steel framing plan respectively, with beams spaced at 10'-0" on center and girders spanning 20'-0" between columns. Beam and girder sizes are typically W10's, W14's and W18's.



A two hour fire rating is achieved by spray proofing the beams and girders.



## Roof system

The roof framing system as hinted earlier, is a structural steel system. It can be broken down into two parts: the main roof/penthouse framing plan and the penthouse roof framing, as shown in Figures 6 and 7. The penthouse roof deck is a 1 ½" deep, wide rib, 20 gage galvanized metal deck.

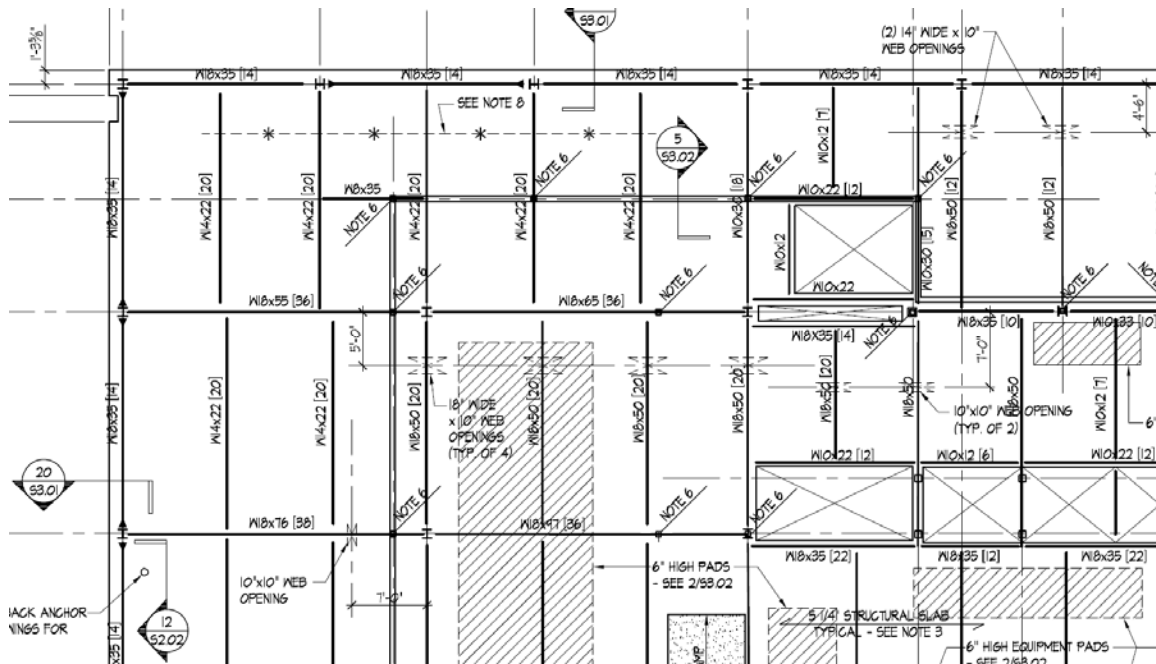


Figure 6 / Partial Main Roof/Penthouse Framing Plan

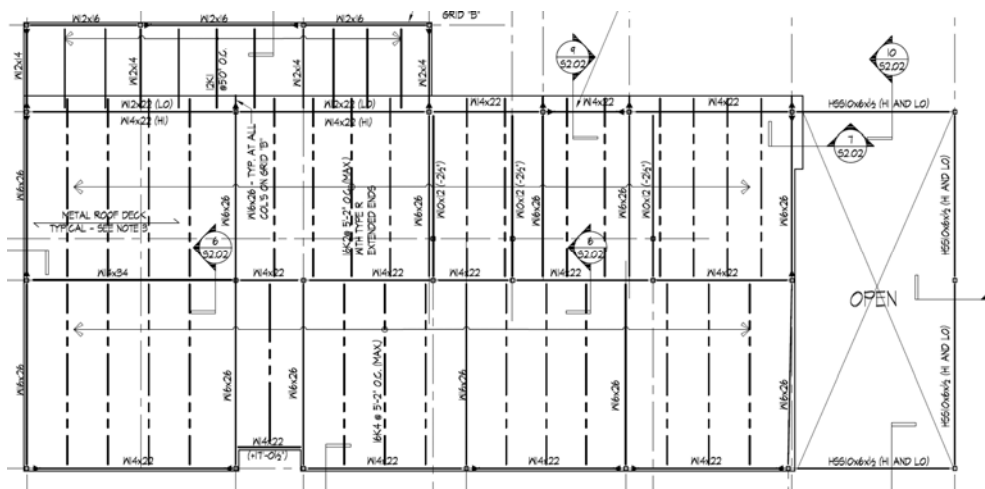


Figure 7 / Penthouse Roof Framing Plan

The penthouse floor framing plan includes an additional framing for the 12000 LBS cooling tower, as seen in Figure 8 and provides requirements for the 6" high equipment pads, as shown in Figure 9

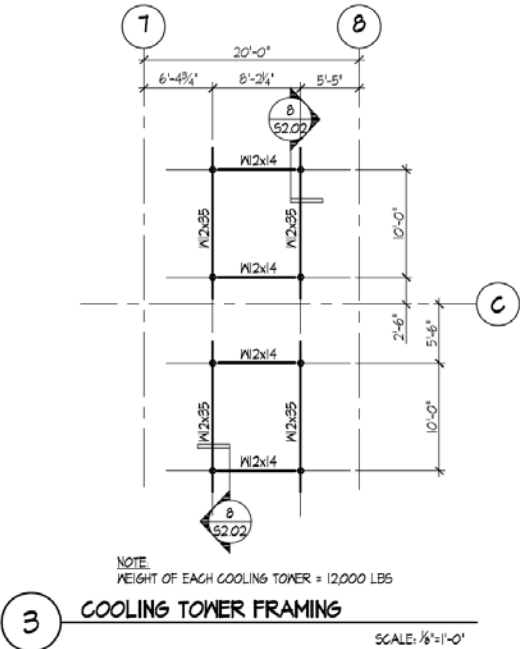


Figure 8 / Cooling Tower Framing Plan

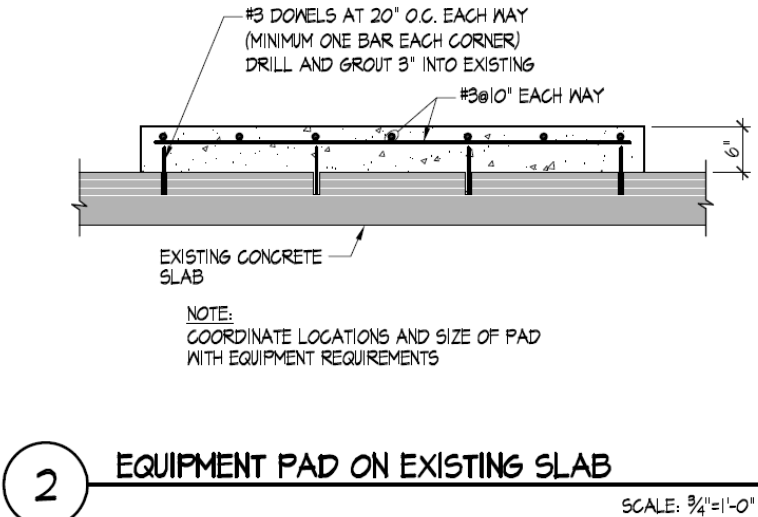


Figure 9 / Equipment Pad Framing

### Typical Bay – Floor system

There are several bay sizes used in 440 First Street. A typical bay, 20' x 20'-11", was selected from the framing plans for floors 2 – 7, and is highlighted in Figure 10 below. Due to the different thicknesses of slabs (7" and 9 1/2") on the typical floors, slab reinforcement varies.

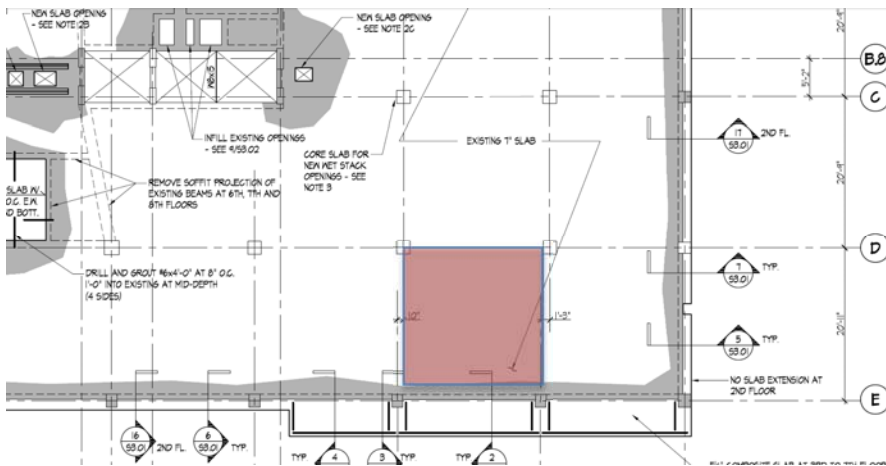


Figure 10 / Typical Bay Shown

For the new additional floors, typical girders will span 20 feet between columns and beams are spaced at 10 feet on center. Figure 11 shows a typical bay size, with beam sizes varying. The most common sizes are W10's, W14's and W18's as mentioned earlier.

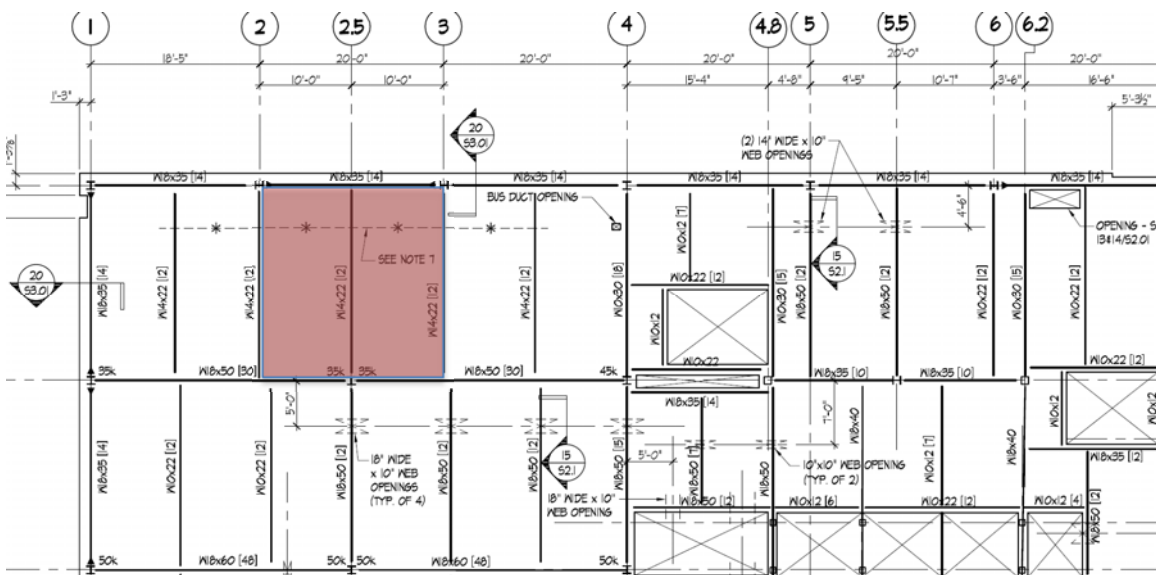


Figure 11 / Typical Bay in Structural Framing

## Columns

From the 8<sup>th</sup> floor, new steel columns were added and centered to the existing columns. The additional framing provides a column layout that creates interior column free space by eliminating the first interior columns on the east side of the building, as shown in Figure 11. The new columns will typically be 10" wide by 10" deep steel wide flange shapes.

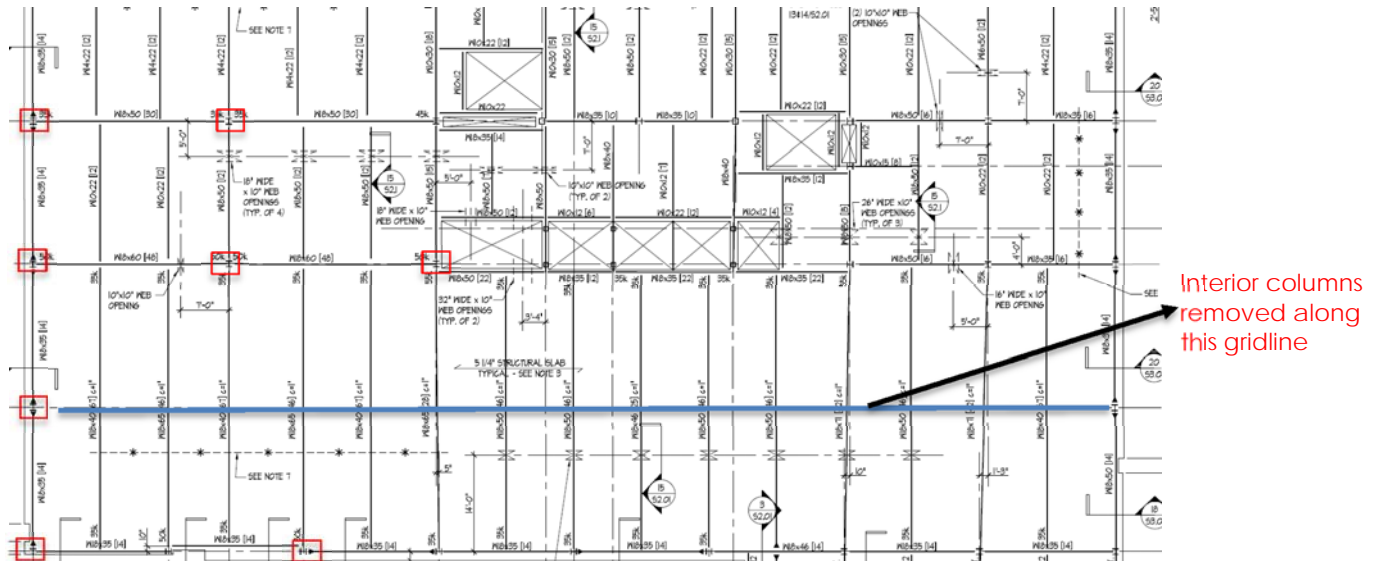
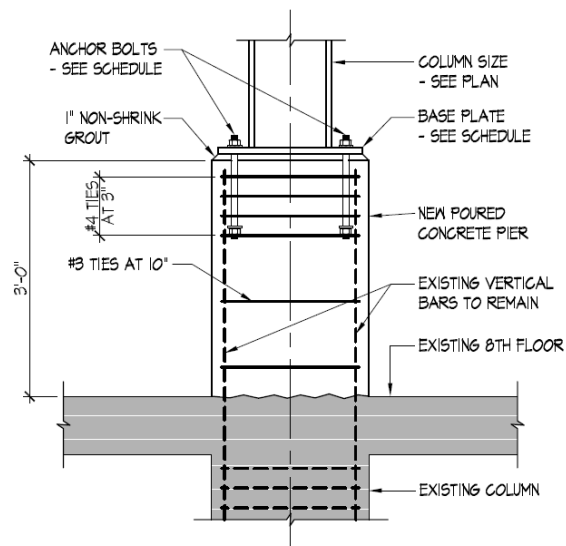


Figure 12 / Steel Columns Highlighted in red

The rebar for the existing concrete column was to be retained for a height of 3' - 0" above the 8<sup>th</sup> floor slab, following the demolition of existing roof and penthouse removal, as shown in the column detail in Figure 13.

Figure 13 / Column Base Detail



A preliminary analysis indicated that removing the existing concrete roof and penthouse roof, in addition to removing the building facade on all 4 sides, provided a column load reduction that enabled the new totals to be comparable to the column loads on the existing base building drawings, after the new steel frame loads were added.

The new building façade consists of a state-of-the-art aluminum curtain wall at the east elevation and masonry walls at the other faces.

## Lateral System

The lateral force resisting system consists of moment connections at the new steel framed levels, and will be used in conjunction with the slab-column frames at the existing levels.

The 2009 International Building Code chapter 34, Section 3403.4, which requires that an existing structure and its addition acting together as a single structure be shown to meet the requirements for wind and seismic design per 1609 and 1613. With that said, it allows an exception which states that load-carrying structural elements, columns and footings in this case, whose demand-capacity ratio with the addition is no more than 10 percent greater than its demand-capacity ratio with the addition shall be permitted unaltered.

Figure 14 and Figure 15 on the next page show the location of the steel moment frames on the new levels and the slab-column frames on the existing levels.

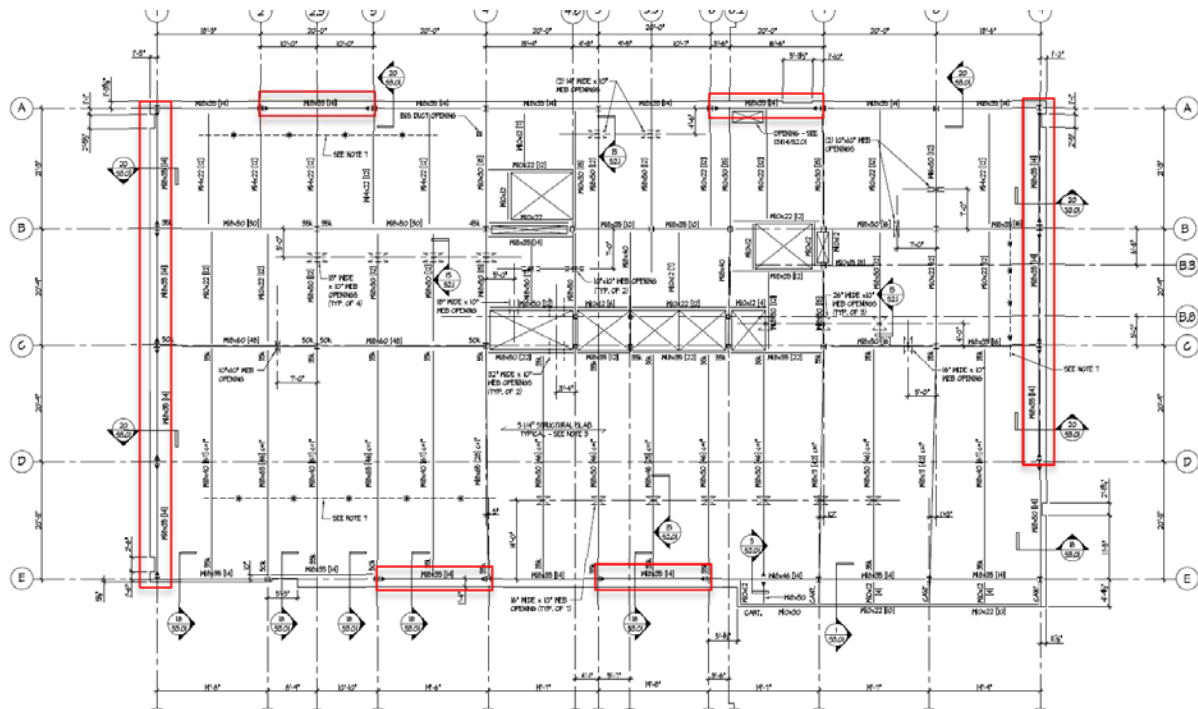


Figure 14 / Steel moment frames highlighted in red



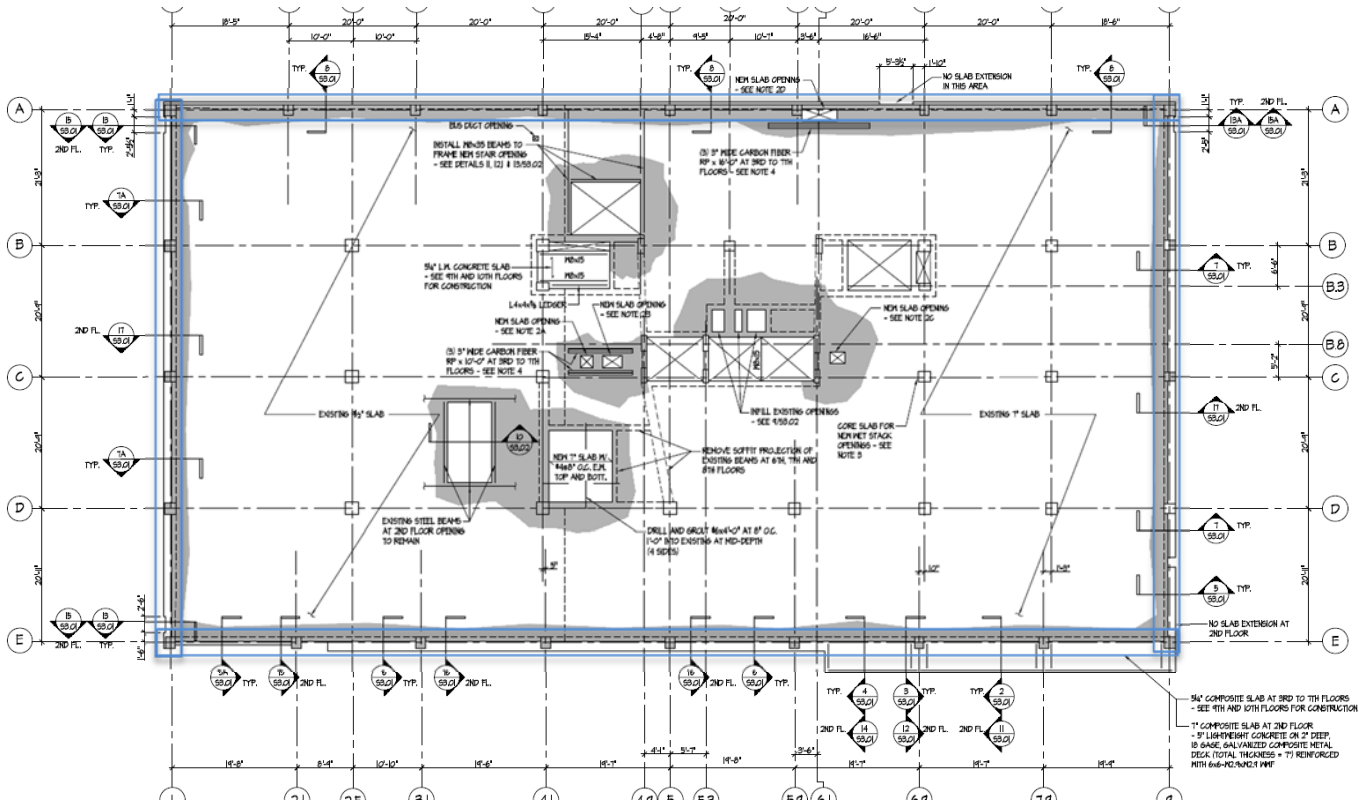


Figure 15 / Slab-Columns Moment Frames Highlighted in Blue

## Foundation System

A geotechnical report was done by Schnabel Engineering Associates in the 1980's. They recommended foundation requirements for the support of the proposed building and floor slabs on grade, after an evaluation and analysis of subsurface conditions. The concrete columns and foundation walls are supported by spread footings.

Recommended design bearing values are 6000 PSF for the column footings and 4000 PSF for the wall footings. With the proposed addition of the new building, no new soil reports were performed since load reduction from removed components outweighed the additional loads from new floors.

A partial cellar plan and a typical footing detail are shown the Figures 16 and 17 respectively.

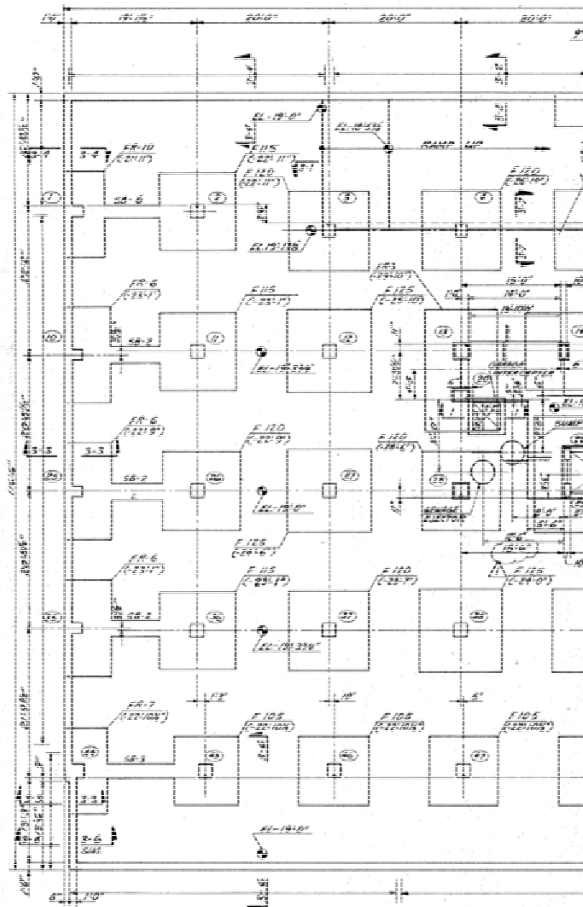


Figure 16 / Partial Cellar Plan

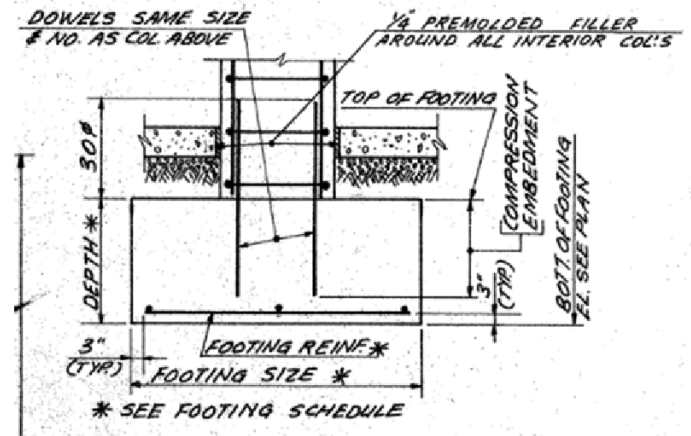


Figure 17 / Typical Footing Detail

## Joint Detailing and Design modifications

Connection detailing is key to the success of any steel structure. It is imperative that the various types of connections are correctly detailed to ensure proper load transfer between various members.

### Steel Moment Connection Detail

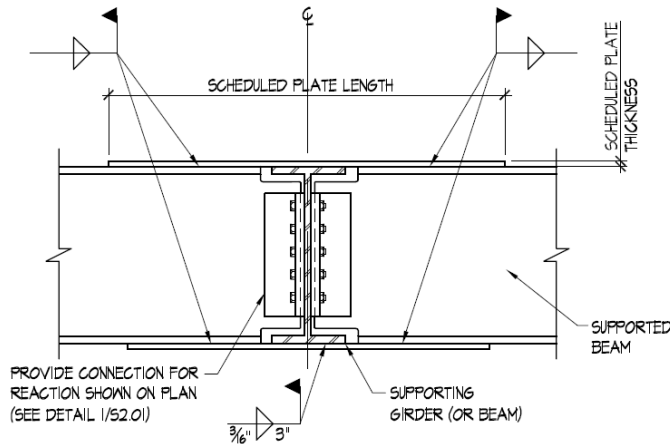


Figure 18 / Moment Connection Detail Beam to Girder

### Beam to Column Connection Detail

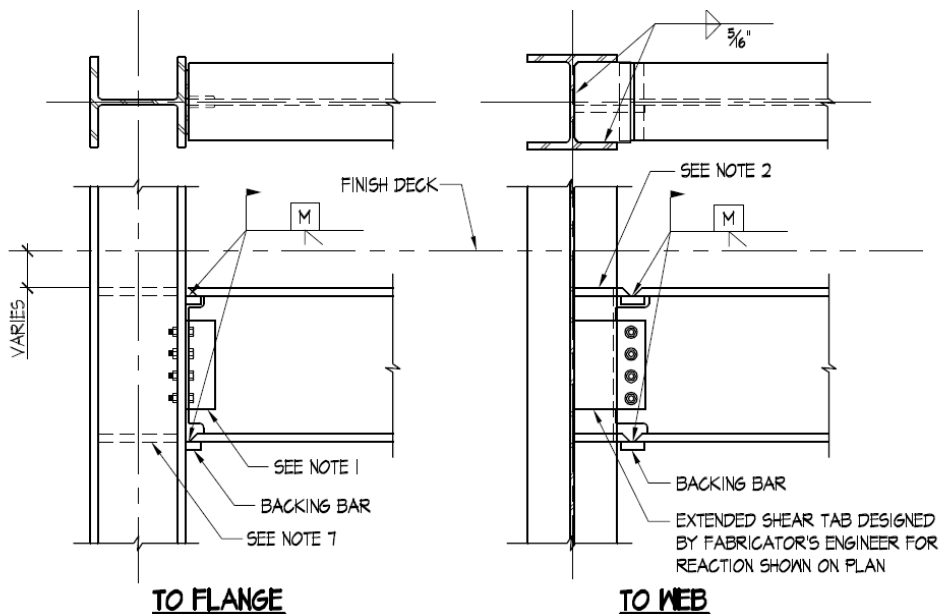


Figure 19 / Beam to Column – Fully Restrained Moment Connection

### Other additional details

With ceiling heights of 8'-4", and a steel frame used to limit the added loads to the existing columns and footings, there was not enough room to accommodate ductwork under the structure. After careful consideration, it was decided to design the steel beams and girders with openings for ductwork and piping. A total of 99 openings were detailed, as shown below, and included in the design.

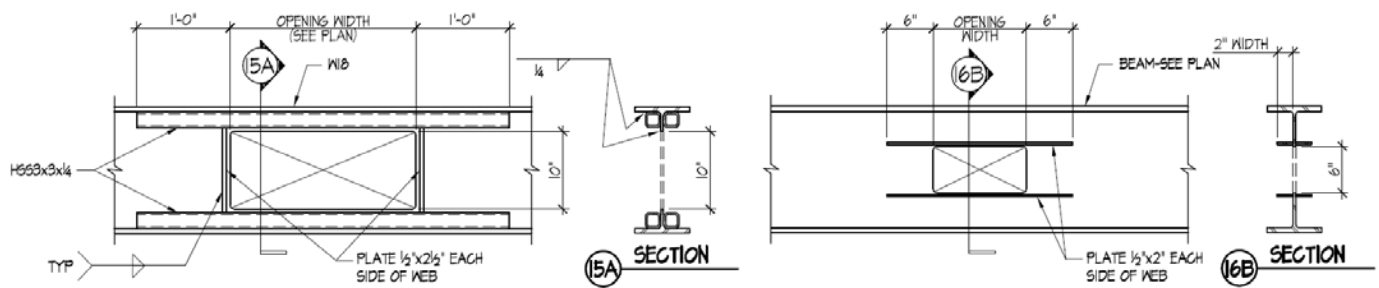


Figure 20 /Web Opening Detail

### **Building Design Codes and Standards**

The structural design is in accordance with the International Building Code, 2006

In addition, the concrete and steel structural systems will conform to the;

- I. "Building Code Requirements for Reinforced Concrete"  
**(ACI 318-11)**
- II. "Specifications for Structural Steel Buildings" **(AISC)**

General codes are listed below;

- a. "District of Columbia building code supplement of 2008, DCMR Building Code." **(D.C. Supplement to the 2006 International Building Code)**
- b. "International Building Code – 2009", **International Code Council**
- c. "Minimum Design Loads for Building and Other Structures",  
**(ANSI/ASCE 7-02-2005) American Society of Civil Engineers.**

## Design Loads

This section focuses on the determination of the design loads. It highlights the building codes and standards used, as well as the load paths that occur in this project.

### National Codes

**Live Load** – ASCE 7-05 Chapter 4 in accordance to IBC 2006

**Lateral Load** – ASCE 7-05 Chapter 6 in accordance to IBC 2006

## Gravity Loads

### Dead Loads

The structural elements will be designed to support the actual weight of the structural framing, mechanical system, and architectural finishes. Dead loads used in this project consists of the superimposed dead loads, in addition to structure dead loads. The load values are listed on sheet S0.01 of the structural drawings.

### Live Loads

Live loads were calculated using Chapter 4 of the ASCE 7-05 and Chapter 16 of IBC 2006. The design live loads are not to be less than the minimum requirements of the Building Code. The following live loads will be used:

▪ Roof	30 PSF
▪ Roof Terrace	60 PSF
▪ Added Floors	100 PSF

Other Live load values are listed on sheet S0.01

### Snow Load

Snow load is only used when the roof live load exceeds 30 PSF

## Lateral Loads

### Wind Load

Wind loads were determined using chapter 6 of ASCE 7-05, section 6.5, in accordance to the IBC 2006. For the purpose of checking design stresses in framing members, wind loads will be based on a



90 MPH wind speed using Exposure Category B. The net penthouse roof uplift is calculated to be 20 PSF.

#### Seismic Load

Seismic loads were calculated using Chapter 12 of the ASCE 7-05, section 12.8., which describes the Equivalent Lateral Force (ELF) method. The building is considered to be in Risk Category II and seismic loading analysis will be based on design category A.

As stated earlier, the removal of the existing concrete roof, penthouse roof, and the building skin on all 4 sides, provided a column load reduction. The existing concrete footings also had some reserve capacity, and it appeared that no footing modifications were required. Using the International Building Code Chapter 34, Existing Structures, for our analysis (Specifically, Section 3403 – Additions) it was determined that the additional gravity load for the steel framing minus the gravity load for the existing roof and columns as well as precast skin/concrete penthouse loads result in a net increase of less than five percent. For seismic loading, thus the demand-capacity ratio increase was less than ten percent. For wind loading, based on an assumed penthouse layout, the demand-capacity ratio increase was slightly greater than ten percent which required further analysis during design. However, due to the frame assembly of cast-in-place concrete slabs and columns and the low story heights, the added wind loading for the addition required no reinforcing or strengthening of the existing columns or footings.

#### Load Path

The gravity loads are received by either the composite floor slab or the roof. These loads are then transferred to the beams and girders, ultimately brought down through the columns into the footings and foundation

Wind loads are first collected by the exterior façade. This load is transferred through the floor diaphragm in to the lateral force resisting systems, which are the steel moment frames and slab-column moment frames in this case. These loads are ultimately transferred into the footings and foundation.

## PROPOSAL

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### PROBLEM STATEMENT

The preceding technical reports, technical reports 3 and 4, aimed to prove the credibility of the structure, as the structural members and frame were checked for both gravity and lateral loads using both hand calculations and computer modeling software. With that said, the new 440 First Street building tackles most of the structural issues that were present prior to its renovation in 2012, however there is still room for improvement.

440 First Street consists of both a concrete (typical floors) and steel (newly added floors + penthouse) structural system and no major problems were observed in the analysis of the structure as aforementioned. However, there is an interest to create uniformity i.e. the use of the same structural system in the entirety of the building.

### STRUCTURAL DESIGN ALTERNATIVE

The new structural system has been selected to be a composite steel joist frame. The entire structural system will be modeled in RAM Structural, with the use of other structural modeling software and design aids. The decision to use this system is based on results from Technical Report 3. The composite steel joist frame was found to be economical and feasible, coupled with other advantages that the system offers.

The lateral system will also be redesigned as the existing lateral system, slab-column moment frames, for the concrete levels are outdated. The proposed lateral system will incorporate steel moment frames and/or shear walls if needed, and will be positioned systematically to ensure relatively close center of rigidities and center of masses on all levels. Furthermore, the proposed lateral system will also be designed to account for any torsional issues that may arise.

A post tensioned system will also be investigated and checked for feasibility and possible advantages.

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## BREADTH TOPICS

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### CONSTRUCTION BREADTH: Cost & Construction Schedule Analysis

An in-depth cost analysis of the proposed composite steel joist frame will be completed and compared to the existing system. Furthermore, the impact on the construction schedule will be examined, noting changes to the critical path and total length of construction. The results will be checked for practicality and economy.

### MECHANICAL BREADTH: Integration of MEP

Changing the entire structural system may have significant effect on the mechanical system, specifically the ductwork and piping. These elements currently passed through openings created in the existing composite beams due to the limited floor to ceiling heights. The use of a composite steel joist frame will accommodate for the ductwork and piping as they can be passed through the open web of the joists or beneath the bottom chord of the joists. The use of shear walls in the core can also have an impact on the MEP system and has to be considered carefully to ensure the proper integration of all the building systems.

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**RESEARCH/ANALYSIS & TASKS**

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**1. Preliminary Research**

- a. Increase RAM & RAM Concept knowledge, as well as other useful software.
- b. Obtain construction cost and construction schedule analysis for the recent renovation in 2012.
- c. Research and investigate the possibility of a Post-Tensioned System

**2. Perform preliminary analysis on the existing foundation.****3. Design Composite Steel Joist Frame**

- a. Design Gravity System
  - i. Determine the superimposed loads from construction documents.
  - ii. Design beams and floor system using specified loads using RAM & RAM Concept
  - iii. Design columns for gravity loads using RAM
- b. Design Lateral System
  - i. Create RAM model of the new structural system including the foundation.
  - ii. Model the new lateral systems (Steel moment frames and/or shear walls).
  - iii. Perform separate analysis using hand calculations on the effectiveness and the credibility of the system.

**4. Compare overall structural analysis of design alternative with the original design. (*Make changes where applicable*)**

- a. Examine how the proposed design affects the building architecturally.
- b. Check the impact of the new steel structure on the foundation.

**5. Breath Topic #1: Cost & Construction Schedule Analysis**

- a. Cost Analysis
  - i. Create a detailed cost analysis of the proposed composite steel joist frame.
- b. Schedule Analysis
  - i. Create a detailed construction schedule analysis of the proposed composite steel joist frame.

- c. Compare cost and possible construction time savings with the existing system.

**6. Breath Topic #2: Mechanical Breadth**

- a. Consider possible issues with new lateral system
- b. Design and detail a feasible and effective layout of the MEP system
- c. Check effect on cost and schedule for the mechanical alterations

**7. Finalize Report & Presentation**

- a. Outline final report
- b. Create and format report
- c. Outline presentation
- d. Create presentation slide show
- e. Finalize report and presentation

**SCHEDULE**

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The schedule for next semester can be seen in the Appendix.



## CONCLUSION

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440 First Street is a 10 story office/retail building (+ Penthouse) that carefully weaves the new and the old, in both design and technical execution. The recent renovation that occurred in 440 First Street makes it a well-rounded structural system. The composite structural steel framing system coupled with the existing the cast-in-place concrete structure provide a seamless structural design balance. However, the building's structural system will be redesigned using a composite steel joist frame. It is a very inexpensive systems compared to other design alternatives considered in Technical Report 3. The typical bay layout will slightly modified and the impact on the architectural layout will also be considered and checked.

The lateral system will be modified as well, and it will be interesting to see how changing this system will affect the structural design, in terms of structural stability.

Changes to the structural system will result in a possible discrepancy in the cost and construction time of the project. Hence, a detailed cost estimate analysis, as well as the impact on construction schedule will be examined.

An MEP integration breadth will be studied. There may be a need to reroute the systems due to the change in lateral systems and the overall structural system. The best possible alternative as to the layout of the MEP systems will be adopted.

A comparison with the existing structural system will help determine its practicality.

## APPENDIX

PROPOSED TIMELINE   JANUARY TO MAY 2016																			
MILESTONE #1				MILESTONE #2				MILESTONE #3				MILESTONE #4							
Break	11-Jan-16	18-Jan-16	25-Jan-16	1-Feb-16	8-Feb-16	15-Feb-16	22-Feb-16	29-Feb-16	7-Mar-16	14-Mar-16	21-Mar-16	28-Mar-16	4-Apr-16	11-Apr-16	18-Apr-16	25-Apr-16	2-May-16		
Analyze existing foundation									SPRING BREAK								FINALS WEEK		
Computer Modeling and Other Preliminary Research																			
	Gravity System Modeling																		
		Design Floor System, Beams, Girders and Columns																	
			Check Gravity System	Lateral System Modeling and Check															
					Design Steel Moment Frames and/or Shear Walls														
								Check Lateral System											
			Mechanical Breadth					Outline and prepare report			Outline and Prepare Report								
								Perform Cost Analysis			Perform Schedule Analysis								
											Organize and Finalize Report								
												Outline and Prepare Presentation							
														ABET Assessment & CPEP Update					
				MILESTONES															
				1	Gravity System Design Complete														
				2	Lateral System Design Complete														
				3	Breadth Analysis Complete														
				4	Final Report & Presentation Complete														
					Gravity and Lateral Design														
					Cost and Schedule Analysis														
					Mechanical Breadth														
					Final Report and Presentation														