

# Thesis Proposal



## 8<sup>th</sup> Street Office Building | Richmond, VA

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## **Thesis Proposal**

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### **Acknowledgements**

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## Thesis Proposal

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### Table of Contents

Executive Summary.....	4
Introduction .....	5
Structural System .....	8
Foundation.....	8
Parking Garage .....	8
Superstructure .....	9
Lateral System.....	9
Problem Statement.....	11
Proposed Solution.....	11
Breadth Topics .....	12
Solution Methods.....	13
Tasks and Tools .....	14
Schedule.....	15
Appendix A – Typical Framing Plans .....	16

## Thesis Proposal

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### Executive Summary

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The 8<sup>th</sup> Street Office Building project is a government office building designed for the state of Virginia. Unfortunately, construction of the building has not come to fruition as a result of a budget deficit. Therefore, design of the building has been on hold since 2008 at approximately 85-90% completion until funds are allocated for the remainder of the project.

It was discovered in Technical Report #3 and through discussions with the structural design engineers that the current lateral system for the 8<sup>th</sup> Street Office Building can be optimized through further analyses. Therefore, the main intent of the proposed thesis will be to investigate the 12" thick reinforced concrete shear walls that are specified to surround the four transportation cores of the building. Boundary elements and coupling beams will be included in the analysis as well as alternative locations for the shear walls in order to reduce torsion effects. Furthermore, braced frames will be considered as another potential lateral system, which will be compared to the fully designed shear walls. The comparison will be based on effectiveness against torsion, weight, cost, and location. The computer program ETABS will be utilized in the design of the lateral systems.

The relocation of the transportation cores has the potential to greatly affect the architecture of the 8<sup>th</sup> Street Office Building. Therefore, movement and flow of the occupants through the building as well as the required means of egress must be considered. In addition, the functions that are displaced by the relocated cores will need to be rearranged within the floor plan.

Finally, the 8<sup>th</sup> Street Office Building is intended to achieve a Silver Certification under the U.S. Green Building Council's LEED for New Construction Version 2.2 Rating System. Many sustainable strategies have already been incorporated, but many more points may be gained through the addition of a green roof that retains and distributes water for use throughout the building. Therefore, a green roof will be considered on the main roof level as well as in place of the existing planters on the terraces. The loads from the green roof will be included in the lateral analysis, and every attempt will be made to provide the occupants with access to the green roof.

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### Introduction

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The new 8<sup>th</sup> Street Office Building will be located in the bustling Richmond, VA commercial district near the Virginia State Capitol Building. It is intended to be a legacy building that will serve both the needs of the state government and the general public. Initially, the Virginia General Assembly will occupy the 8<sup>th</sup> Street Office Building for approximately five years while renovations to the Capitol Building are being completed. After that time, it is expected that various Virginia government agencies will move into the new office building.

The 8<sup>th</sup> Street Office Building will be comprised of 3 1/2 underground parking garage levels with spaces for 201 cars, ten floors above and a mechanical penthouse. The completed building will stand 176'-5" tall and will enclose approximately 307,000 square feet. Rooftop terraces with planters will be an integral part of the construction on the 3<sup>rd</sup>, 7<sup>th</sup> and 10<sup>th</sup> floors.

A secure main lobby on the first floor will efficiently handle high volume traffic to the large assembly areas. Ground level retail will be located on the corner of East Broad Street and 9<sup>th</sup> Street. The remainder of the floors will be open office spaces with meeting areas that can be flexibly rearranged to meet the needs of the various tenants. Finally, a six story atrium will connect the building along its southern edge to the existing 9<sup>th</sup> Street Office Building. The 9<sup>th</sup> Street Office Building is another Virginia government office building, and the atrium is expected to provide seamless passage between the two buildings. See Figure 1 on the next page for a general site plan.

## Thesis Proposal

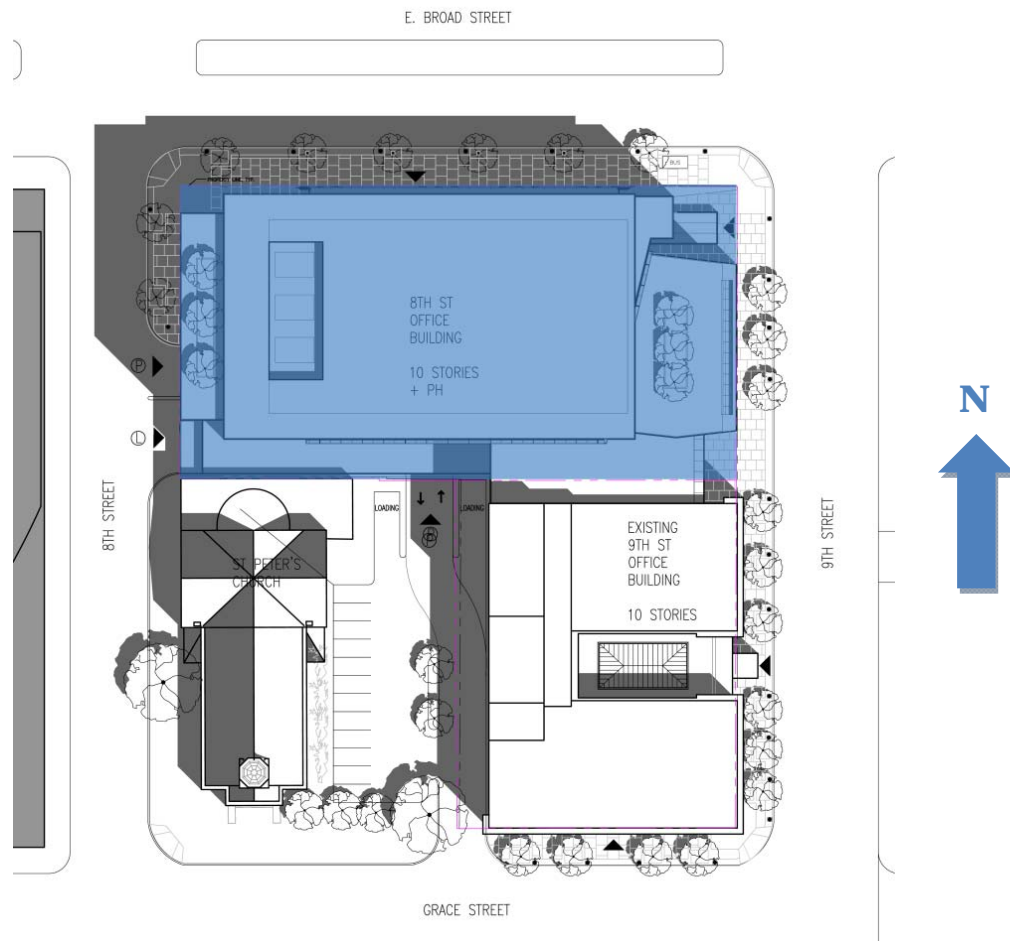


Figure 1 – Site plan

The 8<sup>th</sup> Street Office Building is designed as a primarily steel structure. However, concrete will play a major role in the construction of the underground parking garage and the shear walls around cores within the building. The façade will consist of several different glass curtain walls and precast concrete panels. Aluminum will be used to frame individual windows and doorways. Finally, a standing seam stainless steel roof will cantilever dramatically over 30'-0" off of the mechanical penthouse. See Figures 2 and 3 for elevations that display façade materials and the cantilevered roof. For a more detailed discussion of the 8<sup>th</sup> Street Office Building's structural system, please continue to the next section.

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Figure 2 – Broad Street Elevation



Figure 3 – 9<sup>th</sup> Street Elevation

## Thesis Proposal

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### Structural System

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#### Foundation

The geotechnical engineering study was conducted by Froehling & Robertson, Inc. of Richmond, VA. A total of nine test borings ranging from 50 to 100 feet were performed in September, 2006 and June-July, 2007. Based on the data from the borings and experience with other buildings located in Richmond, it was recommended in the geotechnical report that the 8<sup>th</sup> Street Office Building be supported on a mat foundation system. The mat foundation is located at elevations of 130'-0" and 140'-0" since the fourth and lowest level of the underground parking garage is only located on the western half of the site. Based on the elevations, it was recommended that the 4000 pounds per square inch concrete mat foundation be designed for a maximum allowable bearing pressure of 3,500 pounds per square foot. Ultimately, the mat foundation was designed to be 48" thick reinforced with #10 at 12" each way on the top and the bottom throughout the entire foundation.

According to the geotechnical report, the mat foundation system at the proposed elevations will be above the permanent groundwater table. However, the permanent perched water system may cause a substantial flow of water. Therefore, it was recommended that the 12" thick foundation walls be constructed with a minimum of 6" of free-draining granular filter material. Furthermore, the 48" thick mat should be placed on a 12" layer of free-draining aggregate for drainage and to provide uniform bearing pressure.

#### Parking Garage

The 8<sup>th</sup> Street Office Building's underground parking garage is comprised of 3 ½ levels and can accommodate 201 vehicles. The concrete columns are sized to be 30"x30" and tend to be reinforced with 16 #10 bars. Typical bay sizes are either 20'-0" by 40'-6" or 20'-0" by 30'-0". The concrete beams are typically sized to be 30"x30" although there are several exceptions. The longest span of the beams is approximately 40'-6". Primary reinforcement for the beams ranges anywhere from #7 to #11 bars. The one way concrete slabs span in the 20'-0" direction, and the majority of the slabs are 8" thick and reinforced with #5 bars spaced at 12".



## Thesis Proposal

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### Superstructure

The most typical bay sizes for the 8<sup>th</sup> Street Office Building are either 20'-0" by 40'-6" around the perimeter or 20'-0" by 30'-0" through the middle portion of the building. However, there are several variations due to the shape of the building from floor to floor. The composite floor system consists of 3 ¼" of lightweight concrete and 2" deep, 18 gage metal deck for a total depth of 5 ¼". The deck spans W-shape infill beams spaced at 10'-0" on center. The beams tend to be W16x31, W18x35, or W18x40 depending on the length of their span, which most commonly ranges from 30'-0" to 40'-6". Composite action is achieved between the floor system and the beams through ¾" diameter, 4" long headed shear studs. The beams then transfer their loads to W-shape girders whose sizes vary greatly. The girders are connected to W14 columns that range in size from W14x43 to W14x283. The columns are typically spliced every three floors. See Appendix A for typical floor framing plans.

### Lateral System

The primary lateral load resisting system for the 8<sup>th</sup> Street Office Building consists of reinforced concrete shear walls surrounding four cores within the building. The cores are the locations of the main elevators and stairwells for the building. Therefore, openings are provided in the walls for doorways. There are a total of 16 shear walls. Shear Walls 1 thru 4 extend from the 4<sup>th</sup> floor foundation of the parking garage below grade to the roof. Shear Walls 5 thru 8 extend from the 4<sup>th</sup> floor foundation of the parking garage below grade to the penthouse mezzanine. Shear Walls 9 thru 12 extend from the 3<sup>rd</sup> floor foundation of the parking garage below grade to the penthouse mezzanine. Finally, Shear Walls 13 thru 16 extend from the 3<sup>rd</sup> floor foundation of the parking garage below grade to the penthouse. See Figure 4 for the exact locations of the shear walls in plan. See Appendix B for details of the shear walls in elevation showing their openings. Note that these elevations only extend upwards from the 1<sup>st</sup> floor in order to simplify the lateral force distribution and analysis in this report.

The shear walls are 12" thick and reinforced horizontally with #6 bars spaced at 12" on each face and vertically with #8 bars spaced at 12" on each face. The shear walls are a constant 12" thickness throughout without larger boundary elements. There is, however, heavier reinforcement of four #10 bars in each of the shear wall corners.

It is assumed that the floor system of the 8<sup>th</sup> Street Office Building acts as a rigid diaphragm and transfers the lateral loads due to wind and seismic activity completely to the shear walls in relation to their relative stiffness. The shear walls then carry those loads down to the mat foundation.

# Thesis Proposal

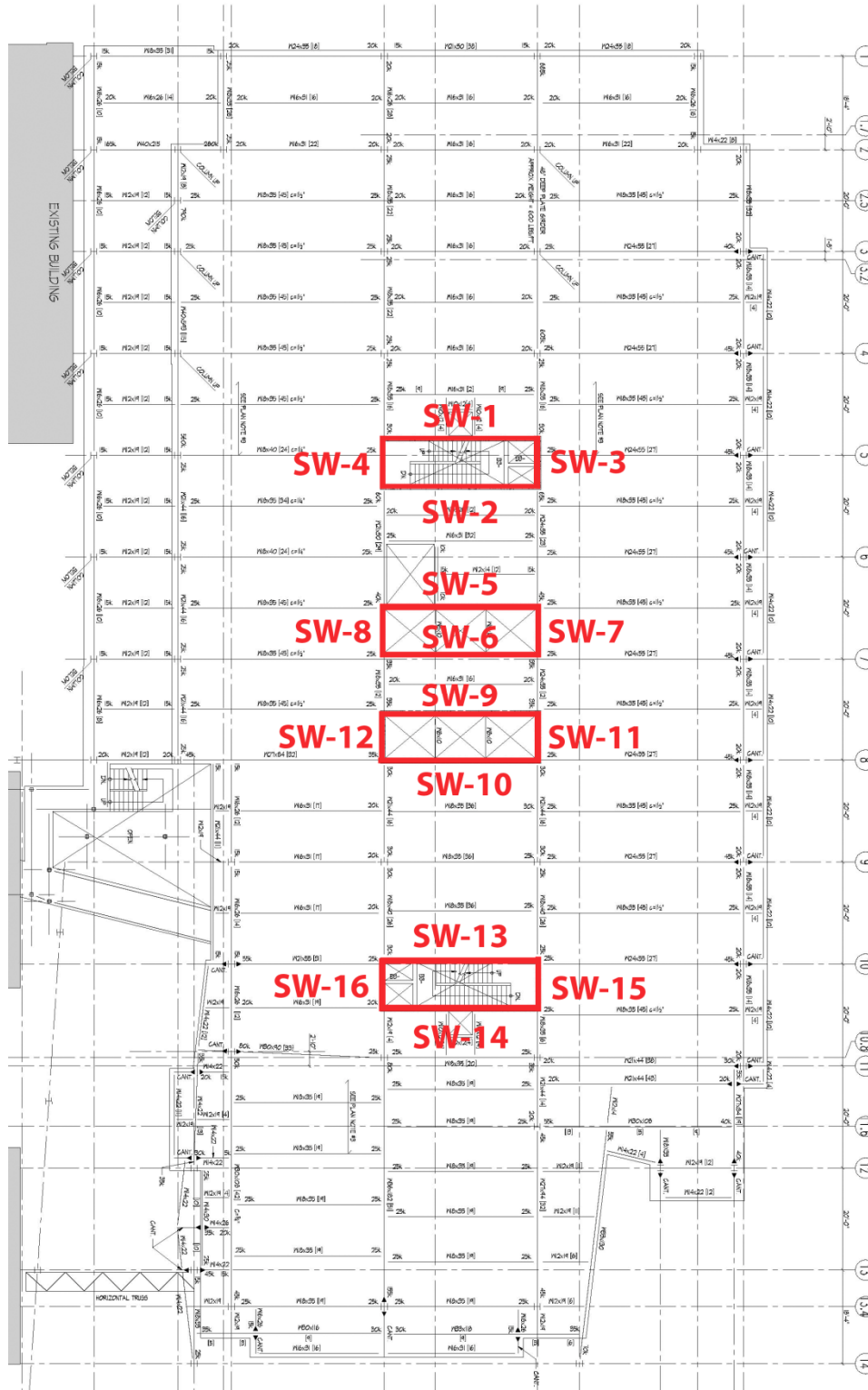


Figure 4 – Locations of Reinforced Concrete Shear Walls

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### Problem Statement

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**Project Goal:** To investigate different lateral system options and layouts in order to reduce and resist torsion, decrease building weight, and lower costs.

Due to the deficit in the Virginia state budget, there are currently no specific plans to finalize the design of the 8<sup>th</sup> Street Office Building and proceed to construction. The most recent set of drawings that was submitted to Virginia's Bureau of Capital Outlay Management is the "Base Building Working Drawing Phase" dated February 29, 2008. After discussions with the structural engineers from Rathgeber/Goss Associates, it was discovered that the lateral system consisting of 12" thick reinforced concrete shear walls was not completely optimized when work ceased to be done on the project. Therefore, the focus of the thesis to be completed next semester will be to fully design the lateral system for the 8<sup>th</sup> Street Office Building under the assumption that the state of Virginia will eventually allocate funds to resume the project.

Based on results from Technical Report #3, torsion is an issue for the shear walls in the North-South direction. Furthermore, seismic loads were found to govern for Shear Walls 1 and 2. Therefore, the ideal lateral system will counteract the effects of torsion as well as decrease the total building weight. Finally, other factors that will affect the choice of lateral system should include cost, constructability, and serviceability.

### Proposed Solution

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The first solution is to complete the design of the current shear walls. As indicated in Technical Report #3, the use of larger boundary elements with more reinforcement may be necessary for the shear walls in their current locations. However, different layouts of shear walls will be taken into consideration with the intention of reducing the effects of torsion. Furthermore, coupling beams will be analyzed around the openings in the shear walls in order to create a more effective and efficient system. Weight, cost, and drift will be determined for each configuration to provide points for comparison.

The second solution is to design braced frames, which will then be compared to the most feasible shear wall design. Once again, different locations of the cores may need to be taken into account, and openings may play a large role in the types of braces. Weight, cost, and drift will also be considered for the comparisons. Furthermore, braced frames may provide the opportunity for easier connections to the superstructure. Finally, gravity members surrounding any cores that are relocated will need to be resized for both the shear wall and braced frame designs.

## Thesis Proposal

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### Breadth Topics

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#### **Breadth Topic #1: Architecture**

Moving the four transportation cores in order to optimize the lateral system has the potential to greatly impact the architecture of the 8<sup>th</sup> Street Office Building. In conjunction with investigating the lateral system options, the architectural effects will be considered. Efficient movement of the occupants is important in a government building where large meetings are held on a daily basis. It is also necessary to consider the separation between employees and visitors in a government building that must be secured from any threats. However, the highest priority will be maintaining all means of egress as required by code. Finally, the spaces that are replaced by new transportation cores will need to be rearranged in plan.

#### **Breadth Topic #2: Sustainability**

The design of the 8<sup>th</sup> Street Office Building incorporates several sustainable strategies in order to achieve Silver Certification under the U.S. Green Building Council's LEED for New Construction Version 2.2 Rating System. In order to achieve an even more sustainable building, a green roof is going to be considered in place of the current planters on the rooftop terraces and extended to the penthouse roof if possible. The green roof will be designed with the intention of retaining water that can be utilized throughout the building. As such, the drainage and flow of water to various areas of the building will be considered. In addition, the hope is that the green roof will be accessible to the building's occupants, so transportation to the green roof will need to be provided. This may be considered in conjunction with the architectural breadth. Finally, loads from the green roof will be applied when investigating the various lateral systems.

## Thesis Proposal

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### Solution Methods

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To determine gravity, wind, and seismic loads according to ASCE 7-05, a complete 3D model of the 8<sup>th</sup> Street Office Building will be created in the computer program ETABS. These loads will be used to design the various lateral system elements, so the comparisons of the systems are more accurate and an objective recommendation can be made. The original model will utilize the existing transportation core locations. The shear walls will be designed according to ACI 318-08. All steel members will be designed according to the AISC 13<sup>th</sup> Edition Steel Construction Manual using LRFD.

Schematic plans will then be generated for new locations of the transportation cores. The center of rigidity of each floor will be taken into consideration when developing the new core locations. IBC 2006 will be used to ensure that all means of egress requirements are still maintained. AutoCAD 2010 will be used to reconstruct the floor plans. Once feasible new locations have been finalized, the 3D ETABS model will be revised accordingly, and the shear walls and braced frames will be designed for the new locations.

Drifts and weights will be calculated in ETABS, and cost data will be obtained from R.S. Means prior to making recommendations in regards to the lateral system options.

## Thesis Proposal

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### Tasks and Tools

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#### 1) Green Roof Breadth Study

- a) Research different green roof options
- b) Choose green roof based on water collection properties, weight, and aesthetics for occupants
- c) Finalize locations of the green roof and loads to be applied to the building
- d) Detail water drainage and retention
- e) Calculate greywater usage and savings within the building

#### 2) Lateral System Options with Existing Core Locations

- a) Create ETABS Model for Lateral Analysis
- b) Obtain more accurate gravity, wind, and seismic loads from the model
- c) Design Shear Walls including boundary elements and coupling beams if necessary
- d) Design Braced Frames
- e) Check lateral drifts against code limitations

#### 3) Architecture Breadth Study

- a) Investigate alternative locations for transportations cores
- b) Determine locations that will help reduce torsion and meet egress requirements
- c) Consider rearrangement of displaced functions
- d) Finalize floor plans

#### 4) Lateral System Options with New Core Locations

- a) Edit ETABS Model with new core locations and obtain revised gravity member sizes
- b) Obtain revised loads
- c) Design Shear Walls including boundary elements and coupling beams if necessary
- d) Design Braced Frames
- e) Check lateral drifts against code limitations

#### 5) Compare Lateral System Options

- a) Overall building weight
- b) Locations of cores
- c) Costs based on R.S. Means

#### 6) Report and Presentation Development

## Thesis Proposal

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### Schedule

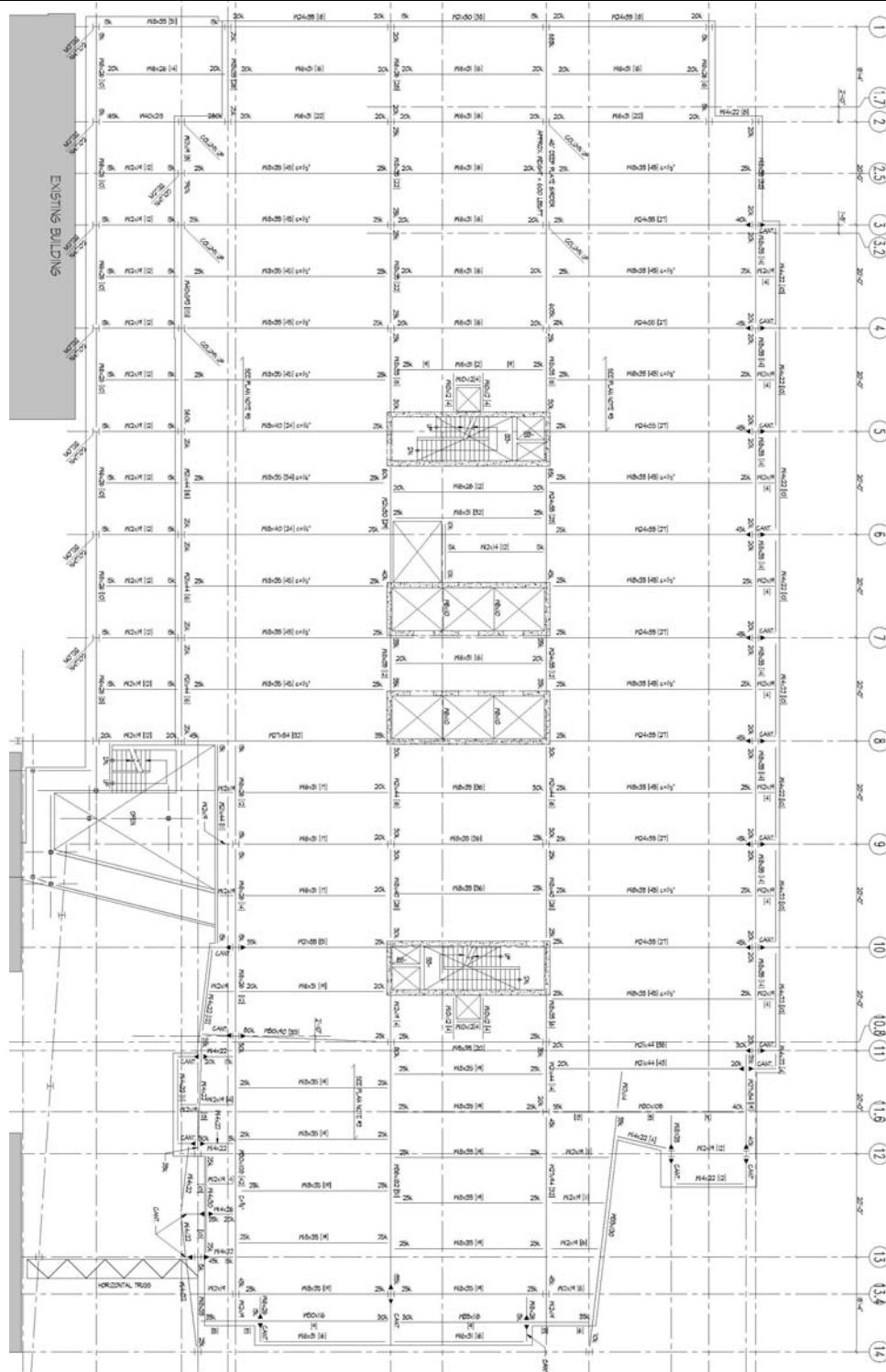
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Task	10-Jan-10	17-Jan-10	24-Jan-10	31-Jan-10	7-Feb-10	14-Feb-10	21-Feb-10	28-Feb-10	Spring Break	14-Mar-10	21-Mar-10	28-Mar-10	4-Apr-10
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- 1) Green Roof Breadth Study
- 2) Lateral System Options with Existing Core Locations
- 3) Architecture Breadth Study
- 4) Lateral System Options with New Core Locations
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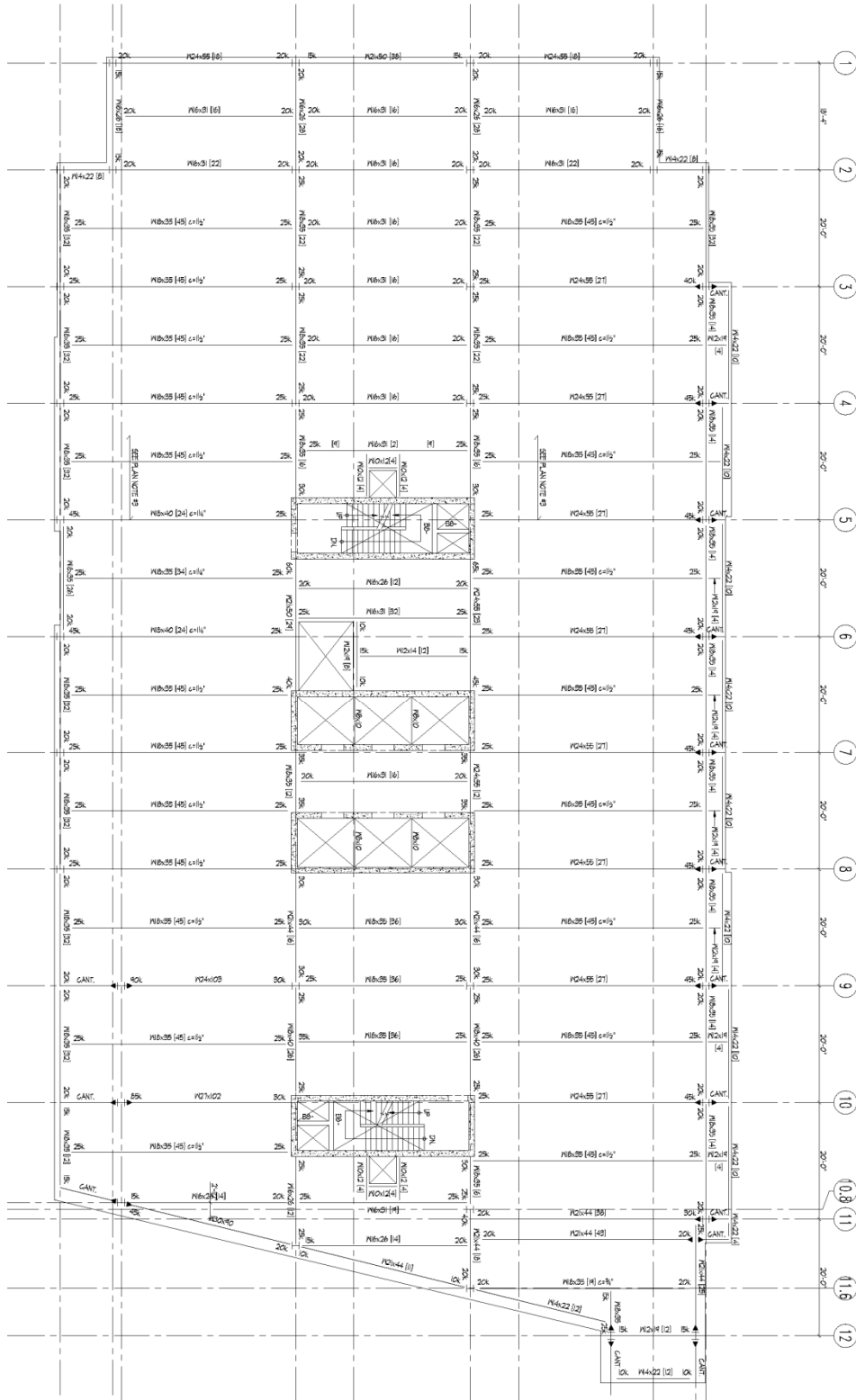
## Appendix A – Typical Framing Plans



3<sup>rd</sup> Floor Framing Plan



# Thesis Proposal



8th Floor Framing Plan