Thesis Proposal

8th Street Office Building | Richmond, VA

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Acknowledgements

I am very grateful to the firm of Rathgeber/Goss Associates for their sponsorship of the 8th Street Office Building for AE Senior Thesis. Also, this thesis would not be possible without the assistance of Commonwealth Architects, which provided the renderings.

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Executive Summary

The 8th 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 8th Street Office Building can be optimized through further analyses. Therefore, the main intent of the proposed thesis will be to investigate alternative lateral systems to the existing 12" thick reinforced concrete shear walls that are specified to surround the four transportation cores of the building. The alternative systems that will be considered are braced frames and steel plate shear walls. Initially, the alternative systems will be designed using the existing locations of the transportation cores as well as the loads that were calculated in Technical Report #1. This will provide a basis for comparison of the existing and alternative lateral system. The comparison of the systems will be based on a variety of factors including weight, cost, constructability, and serviceability. The computer program ETABS will be utilized in the design and comparison of the lateral systems. Finally, one optimal lateral system will be chosen from the existing system of reinforced concrete shear walls and the two proposed alternative systems.

The overall service core of the 8th Street Office Building will then be redesigned in an attempt to minimize its effect on useable space for the tenants. Movement and flow of the occupants through the building as well as the required means of egress will be considered. As a result, the transportation cores may be relocated and have an effect on the lateral system.

The 8th Street Office Building is also 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 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 water drainage and retention will be designed, and water savings will be calculated.

Finally, the optimal lateral system will be redesigned according to the new transportation core locations and with the additional load from the green roof.

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Introduction

The new 8th 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 8th 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 8th 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 3rd, 7th and 10th 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 9th 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 9th Street Office Building. The 9th 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.

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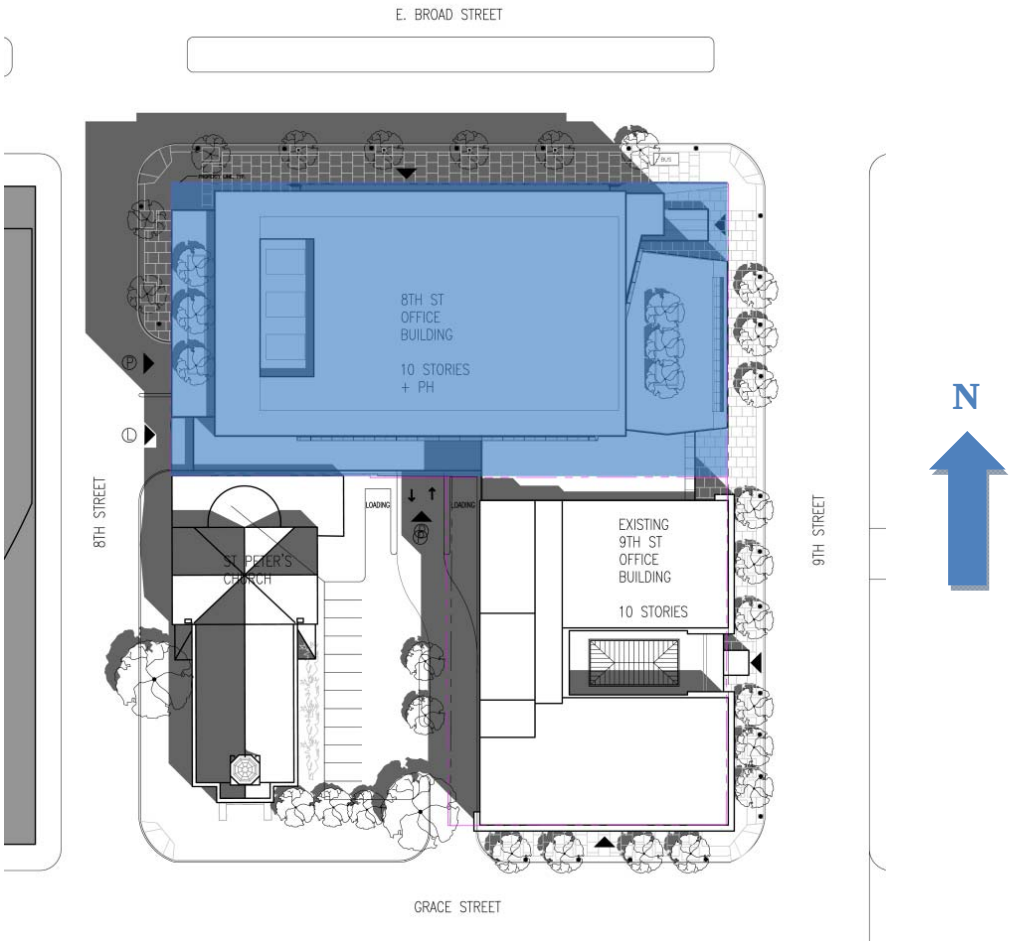

Figure 1 – Site plan

The 8th 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 8th Street Office Building's structural system, please continue to the next section.

Figure 2 – Broad Street Elevation

Figure 3 – 9th Street Elevation

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Structural System

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 8th 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 8th 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".

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Superstructure

The most typical bay sizes for the 8th 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 8th 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 4th floor foundation of the parking garage below grade to the roof. Shear Walls 5 thru 8 extend from the 4th floor foundation of the parking garage below grade to the penthouse mezzanine. Shear Walls 9 thru 12 extend from the 3rd floor foundation of the parking garage below grade to the penthouse mezzanine. Finally, Shear Walls 13 thru 16 extend from the 3rd 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 1st 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 8th 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.

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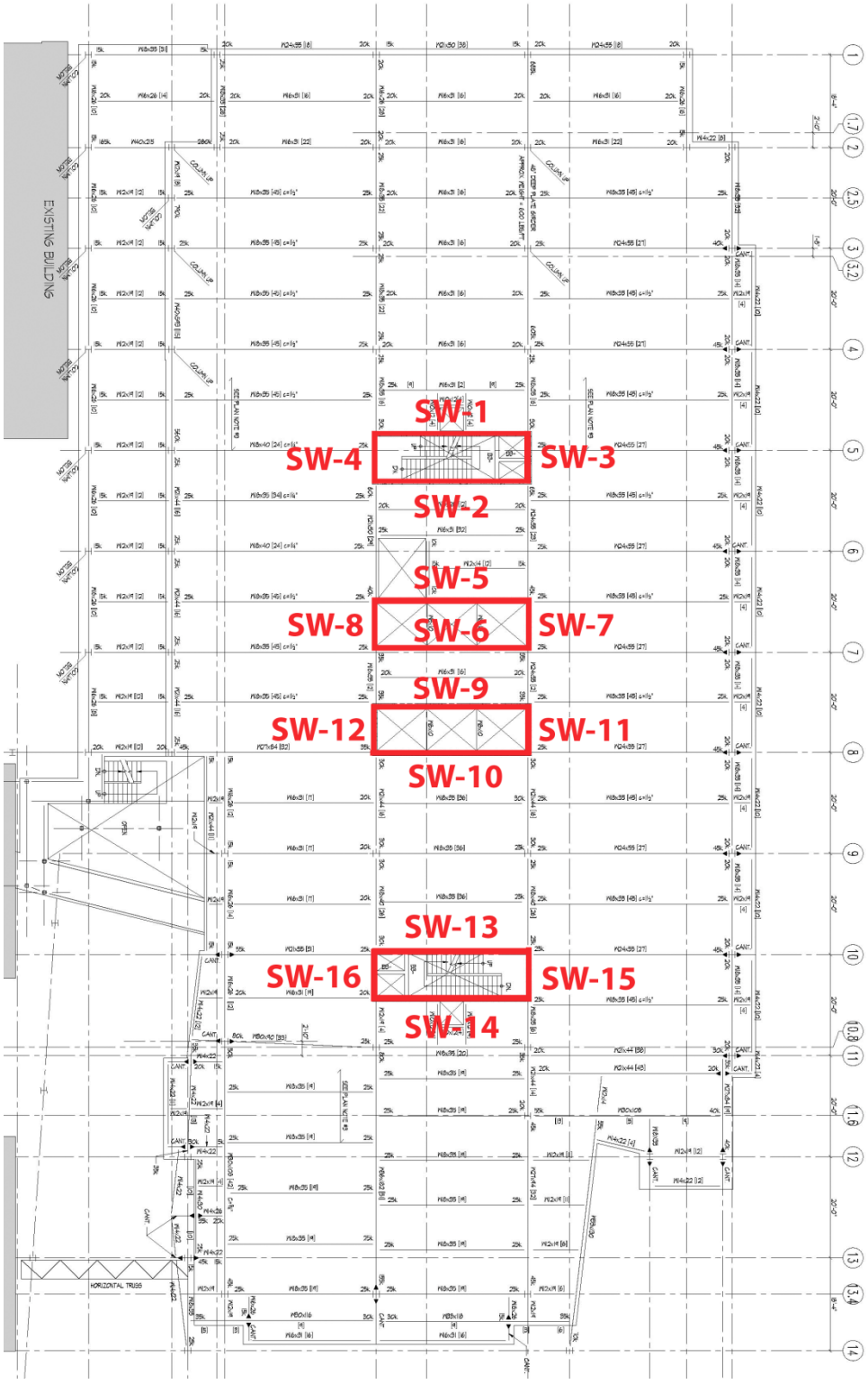

Figure 4 – Locations of Reinforced Concrete Shear Walls

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Problem Statement

Project Goal: To investigate alternative lateral systems including braced frames and steel plate shear walls.

Due to the deficit in the Virginia state budget, there are currently no specific plans to finalize the design of the 8th 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 proposed thesis will be to investigate and fully design alternative options for the lateral system under the assumption that the state of Virginia will eventually allocate funds to resume the project. Factors that should be considered include building weight, cost, constructability, serviceability, and the system's ability to resist torsion.

Proposed Solution

The first solution is to design braced frames around the main transportation cores. Different locations of the cores may need to be taken into account according to potential architectural changes. Furthermore, openings may play a large role in the types of braces that are used. Weight, cost, and drift will also be considered in order to compare the various lateral systems. Other considerations include the fact that braced frames may provide the opportunity for easier connections to the superstructure and require less time to construct.

The second solution is to design the steel plate shear walls. It is expected that the use of steel plate shear walls may decrease the number of shear walls needed to withstand the lateral load on the 8th Street Office Building. This may allow for more flexibility when redesigning the architecture of the service areas of the building as a breadth topic for the proposed thesis. Furthermore, steel plate shear walls may greatly minimize the required thickness of the walls surrounding the transportation cores, which could provide more useable floor space. Of course, factors such as weight, cost, drift, and constructability will also be considered in order to compare the steel plate shear walls to the braced frames and existing reinforced concrete shear walls.

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Breadth Topics

Breadth Topic #1: Architecture

In conjunction with the investigation of alternative lateral systems, the overall service core of the 8th Street Office Building will be analyzed. The goal will be to redesign the number of elevators, stairwells, and restrooms as well as their accompanying locations in order to minimize the effect of the overall service core on the useable floor space for the tenants. In a government building where large meetings are held on a daily basis, the efficient movement of the occupants is important. It will also be 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. It is anticipated that the rearrangement of the service core may have a positive effect on the locations of the transportation cores in regards to optimizing the lateral system.

Breadth Topic #2: Sustainability

The design of the 8th 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 and designed. Water savings will also be calculated. 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.

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Solution Methods

Initially, the alternative lateral systems will be designed utilizing the existing locations of the four transportation cores in order to provide a basis for comparison to the existing lateral system of reinforced concrete shear walls. In addition, the gravity, wind, and seismic loads that were determined in Technical Report #1 will be utilized. In Technical Report #3, a 3D model was created in the computer program ETABS of the existing lateral system for the 8th Street Office Building. This model will be modified to assist in the design of the braced frames and steel plate shear walls. Hand calculations will be performed in order to verify the results from ETABS. All steel members will be designed according to the AISC 13th Edition Steel Construction Manual using LRFD. The steel plate shear walls will be designed utilizing the AISC Steel Design Guide 20. Drifts and weights will be calculated in ETABS, and cost data will be obtained from R.S. Means. Once all three lateral systems have been compared, one will be chosen as the optimal system and will be investigated further.

Schematic architectural plans will be generated for the redesigned service core, and the new transportation cores will be used to design the optimal lateral system. 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. In addition, the load from the newly designed green roof system will be added to the structure. The 3D ETABS model will be revised accordingly and utilized in the design of the optimal lateral system according to the new architecture and additional green roof load.

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Tasks and Tools

1) **Lateral System Options with Existing Core Locations and Loads**
   a) Design Braced Frames
   b) Design Steel Plate Shear Walls
   c) Determine cost, weight, constructability, etc. for each option
   d) Compare the three lateral system options and choose the optimal system
2) **Architecture Breadth Study**
   a) Investigate alternative locations for transportations cores, restrooms, etc.
   b) Determine floor plan that will minimize the service core
   c) Consider effects of new transportation cores on the lateral system
   d) Finalize floor plans
3) **Green Roof Breadth Study**
   a) Choose green roof based on water collection properties, weight, and aesthetics for occupants
   b) Finalize locations of the green roof and loads to be applied to the building
   c) Detail water drainage and retention
   d) Calculate greywater usage and savings within the building
4) **Optimal Lateral System with New Core Locations and Loads**
   a) Edit ETABS Model with new core locations
   b) Obtain revised loads
   c) Design optimal lateral system
5) **Report and Presentation Development**

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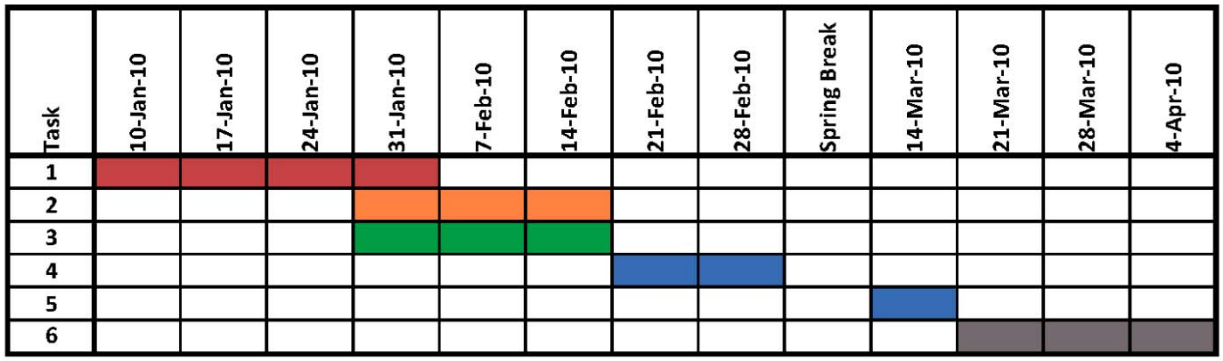
Schedule



1) **Lateral System Options with Existing Core Locations and Loads**
2) **Architecture Breadth Study**
3) **Green Roof Breadth Study**
4) **Optimal Lateral System with New Core Locations and Loads**
5) **Report and Presentation Development**

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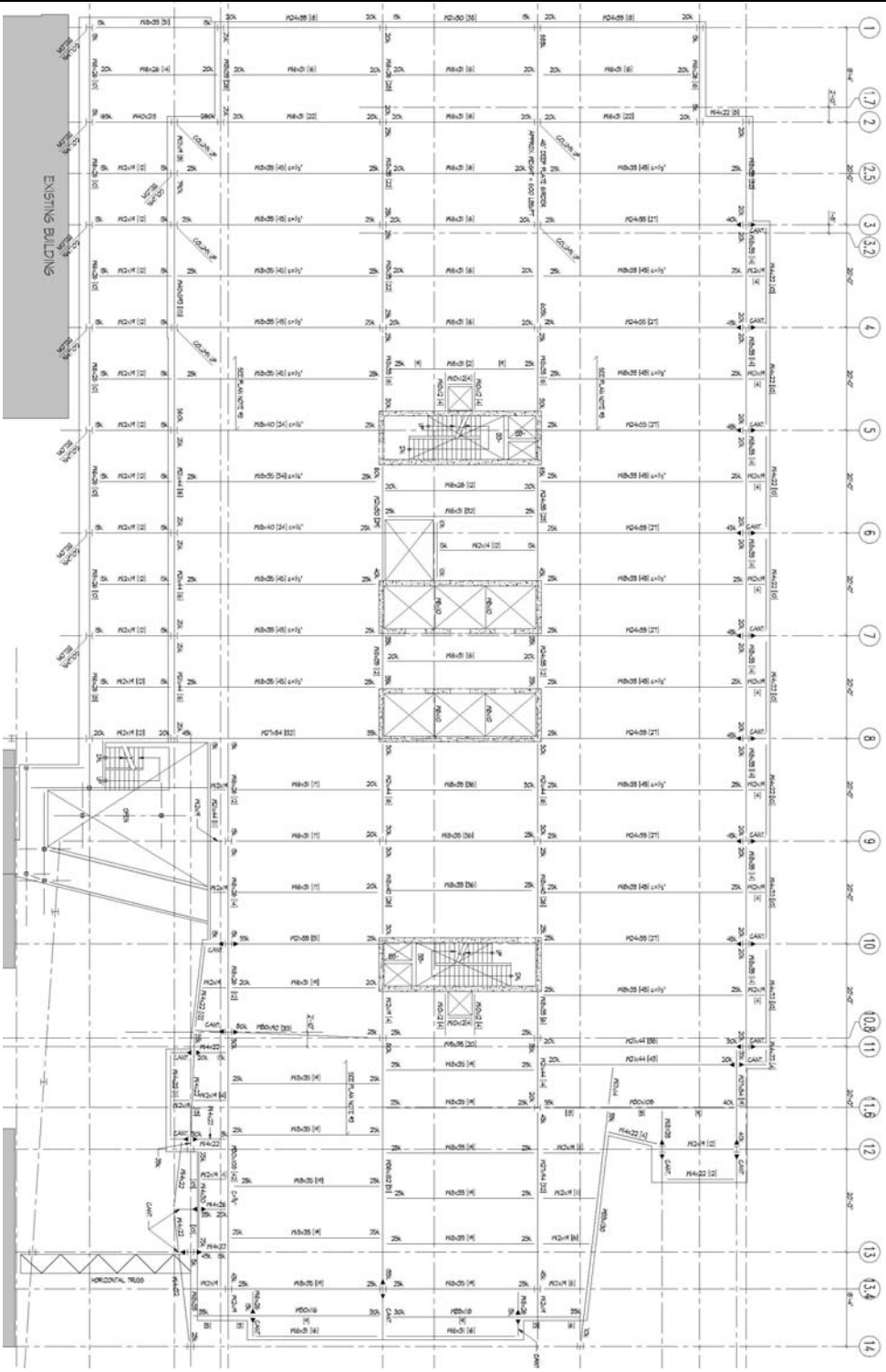
Appendix A – Typical Framing Plans



3rd Floor Framing Plan

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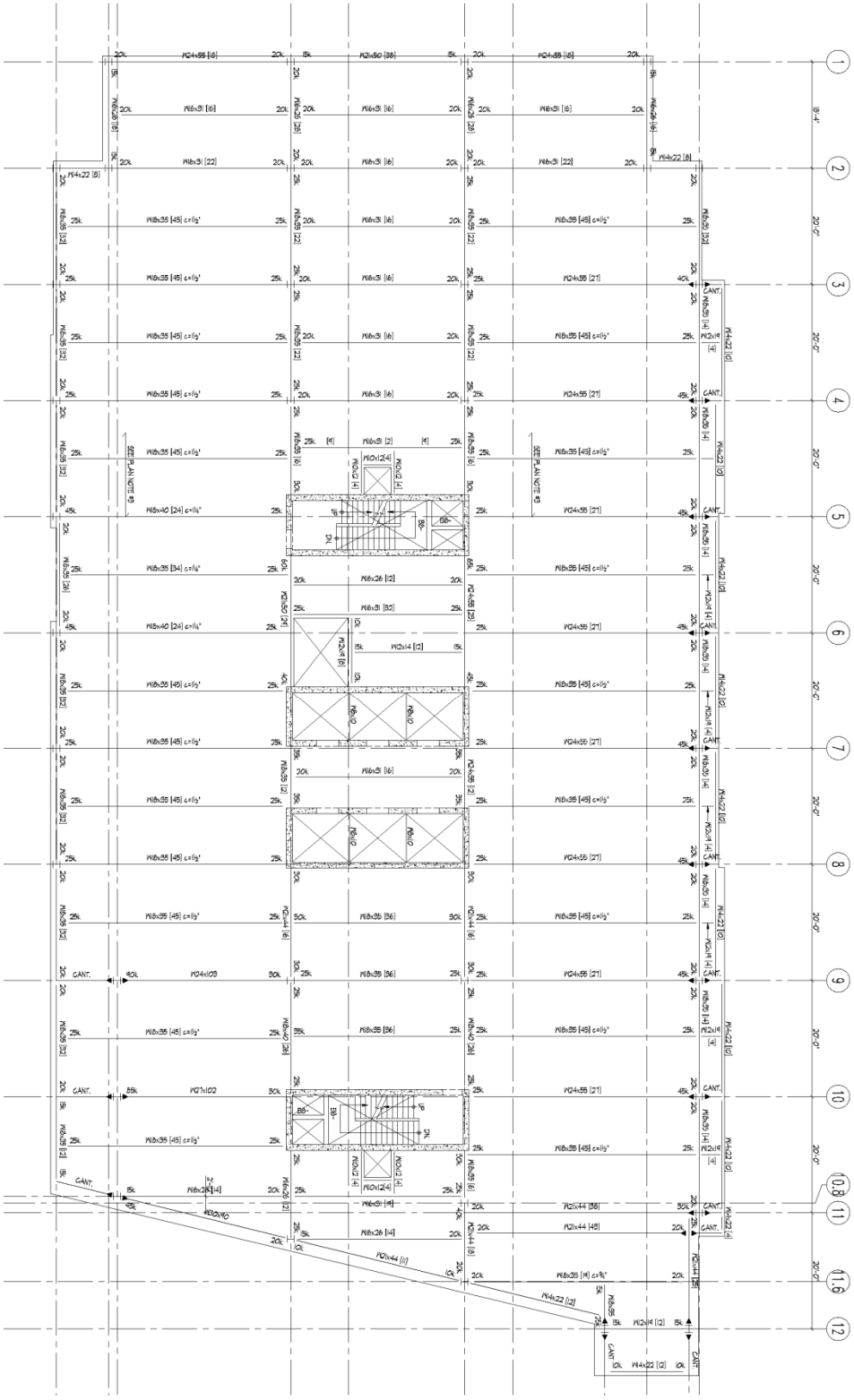

8th Floor Framing Plan