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The Helena
New York City, NY
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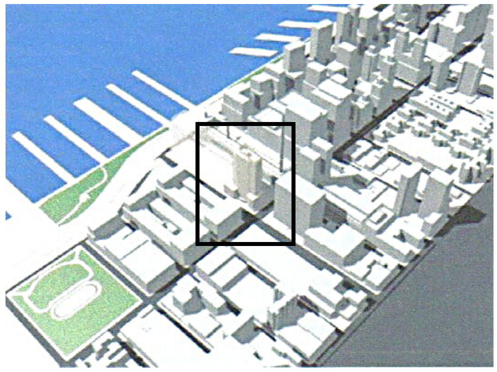

Pictures courtesy of Fox & Fowle Architects

Lateral System Analysis and Confirmation Design

Executive Summary

This document provides a summary of the lateral bracing system used in The Helena as well as an analysis of that system. The walls are composed of reinforced concrete which is to be designed to the strength of the columns on the same level. There are seven shear walls total, six of which run for the entire height of the building. Some of these have sections which support both directions that were taken into account. From running the analysis of the drift for the walls, it is noticed that the shear walls for this building are not the only lateral resisting elements. The placement of the columns and the use of the flat plate slab as a rigid diaphragm show that these elements will aid in the resistance of the lateral force placed on the building. For the area surrounding the building core featuring the elevator lobby, the foundation is aided by the use of rock anchors which shows that the walls in that area will transfer an overturning moment into the foundation. The placement of the shear walls and columns around the core gives the impression that they could be working together as a frame to help resist the lateral force and reduce the amount of deflection per member of the frame.

Introduction

The Helena is a 40-story apartment building in New York City, New York. It stands approximately 400 feet tall and has a total area of about 600,000 ft^2. The below grade floors (the sub-cellar and cellar) are mixed use areas which are used for parking, storage and utility service rooms. The lower floor layout resembles an upside-down U-shape and the rest of the floors above that have a layout which closely resembles a rectangle. This layout makes up most of the floors of the building and has approximate dimensions of 195' wide by 70' deep. The gravity system for the building is composed of 8" flat plate slabs supported by reinforced concrete columns. The lateral system is composed of shear walls which help support the building in both directions.

BUILDING STRUCTURAL SYSTEMS

Foundation

The foundation transfers the gravity and lateral loads of the building through the use of spread and monolithic footings. The footings are to bear on undisturbed rock with a minimum bearing capacity of forty tons per square foot. Also, some of the footings are to be further secured into the rock using 100-ton rock anchors. The footings are designed to rest on a 2" mud slab.

Gravity System

The typical floor system for The Helena is an 8" two-way flat plate slab supported by concrete columns. The compressive strength for the concrete slabs is 5950 psi up to the 20^{th} floor and 5000 psi for the remaining floors. All the concrete is 60 ksi steel reinforced and is composed of a 45% furnace slag concrete mixture. The ground and cellar levels are a 12" flat plate slab and the sub-cellar is an 18" flat plate slab. Columns for the system have a concrete compressive strength of 8000 psi up to the 19^{th} floor, 5950 psi up to the 29^{th} floor, and 5000 psi for the remaining floors. The columns are designed as both rectangular and circular and are laid out in a manner that does not make it easy to determine regular bay sizes which does not make it possible to design a typical bay which can be implemented over the entire floor.

Lateral System

Shear walls which run the entire height of the building make up the lateral support system for The Helena. The shear walls will resist the wind and seismic lateral forces on the building. The concrete strength of the shear walls is to be the same as that of the columns on the same levels, which is noted in the previous section. There are 7 shear walls (A,B,C,D,E,F,G) supporting the lateral load up to the 7^{th} floor and from the 8^{th} floor to the 38^{th} floor, there are 6 shear walls (B,C,D,E,F,G) to take the loads. On the 39^{th} floor, there are 4 shear walls (D,E, part of C, and part of F) which are designed for lateral support. The shear walls are designed to be 16" thick from the sub-cellar the the 24^{th} floor, 14" thick from the 25^{th} floor to the 34^{th} floor, and 12" thick for the remaining floors. All of the shear walls are not typical through their entire height however. Shear wall

G is a non-typical wall because it is shifted 8'-1" to the right and 6'-1.5" down at the 8^{th} floor. Shear wall B is shortened by 6'-0" when the floor plan changes at the 11^{th} floor. For the walls that are rectangular and constant, their design can be treated like large cantilever beams, but the other walls have a more complicated design.

Shear Wall Locations

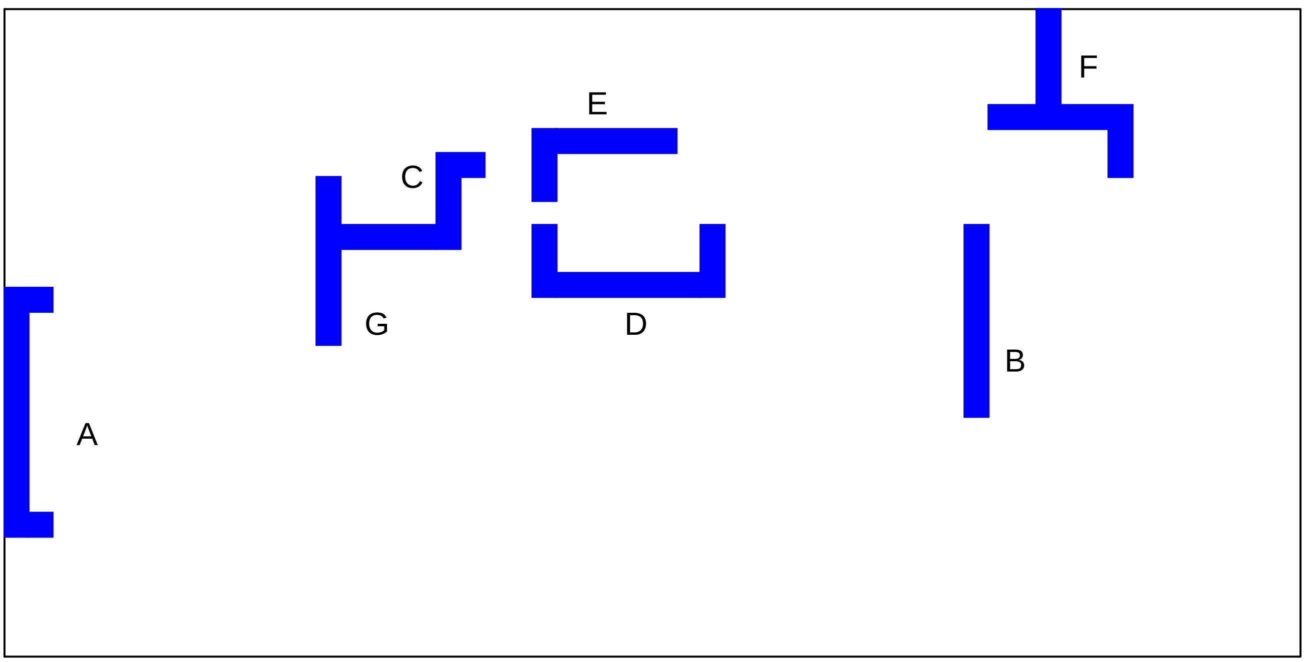

Figure 1. Shear wall layout for the sub-grade levels

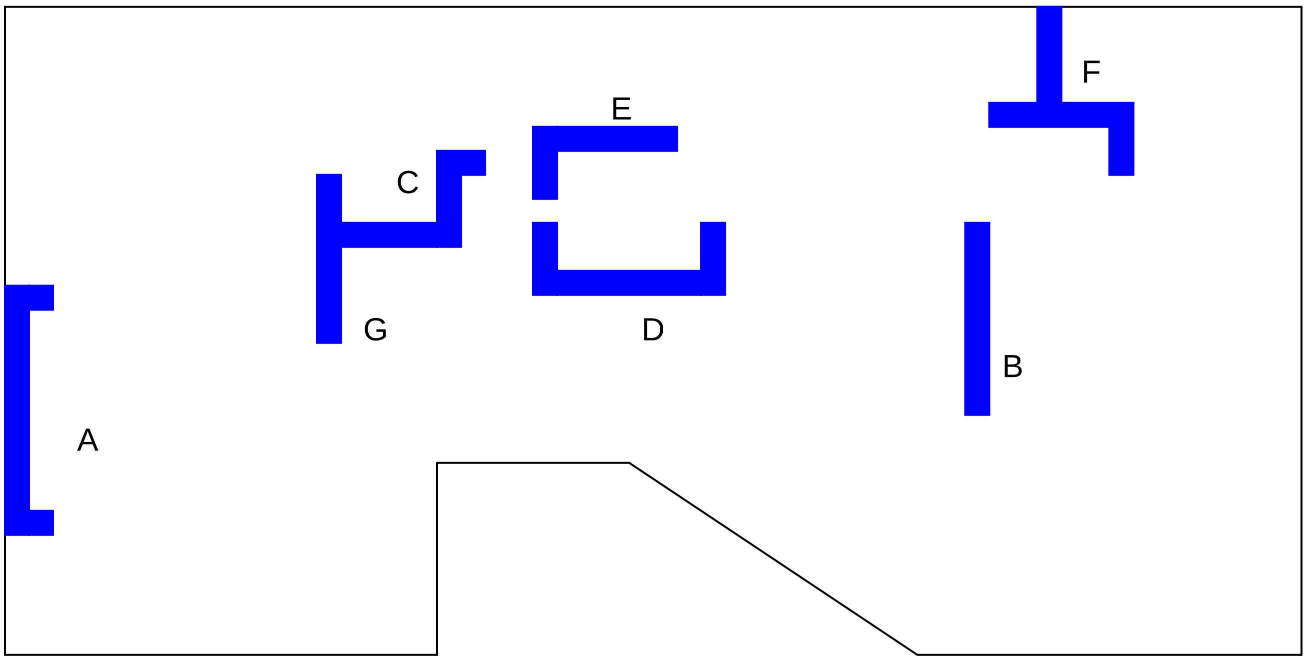

Figure 2. Shear wall layout for the ground floor

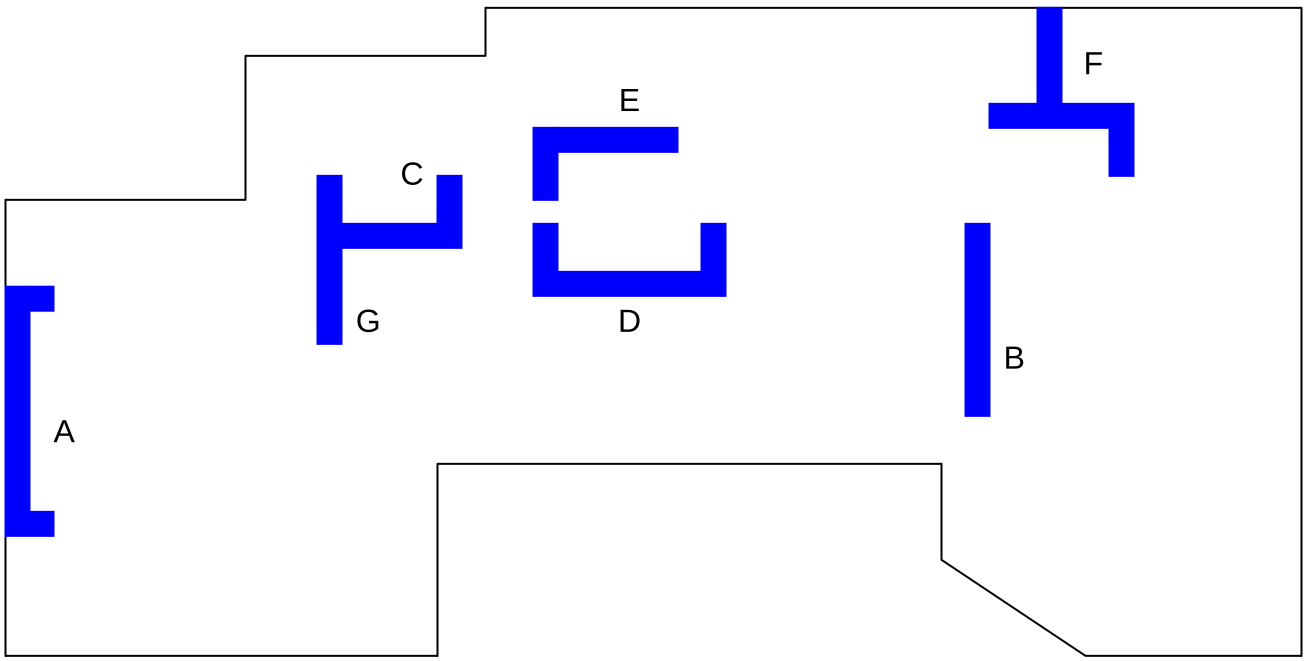

Figure 3. Shear wall layout for floors 2-7

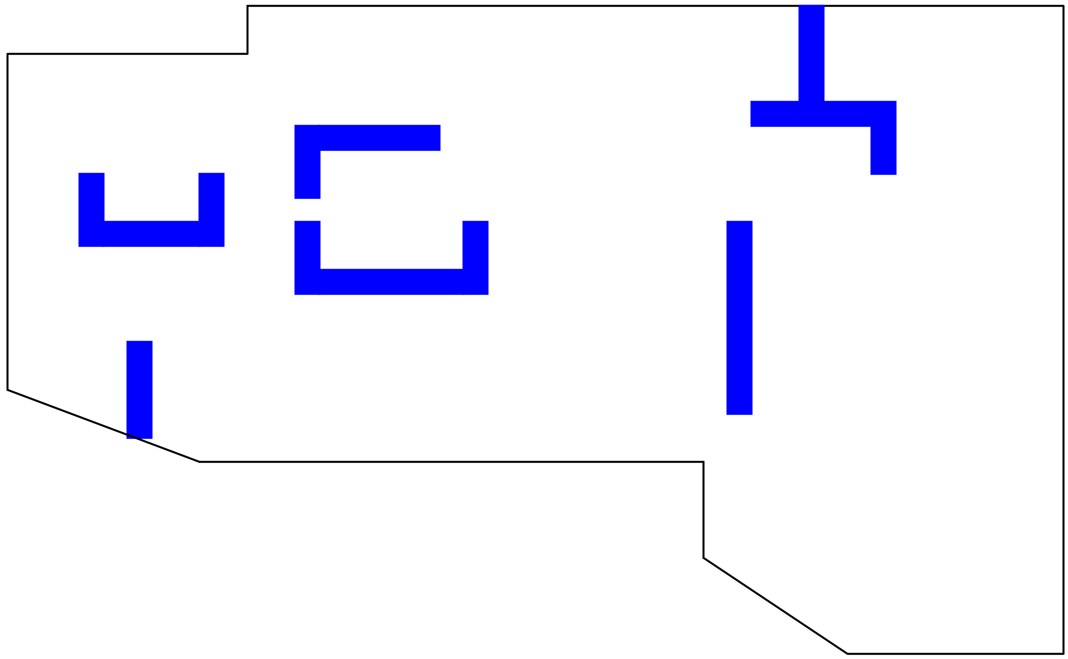

Figure 4. Shear wall layout for floors 8-10

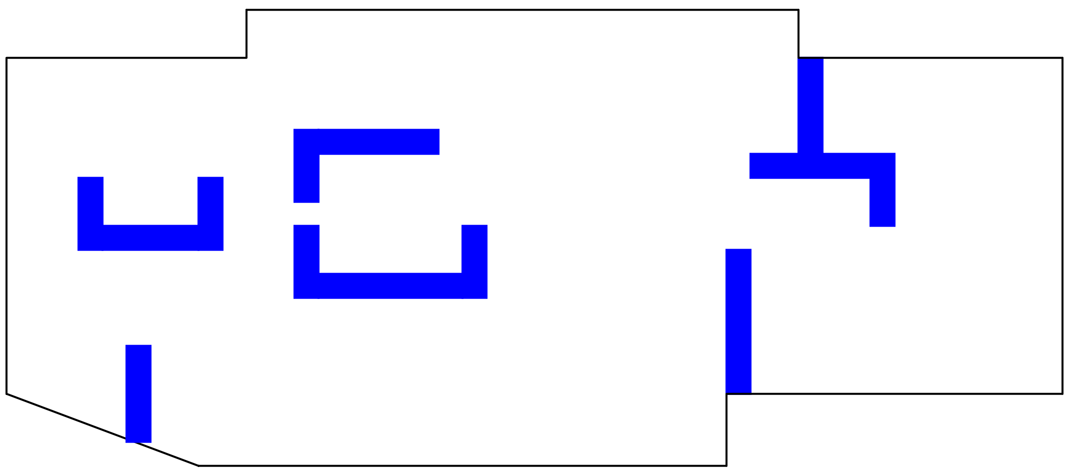

Figure 5. Shear wall layout for floors 11-38

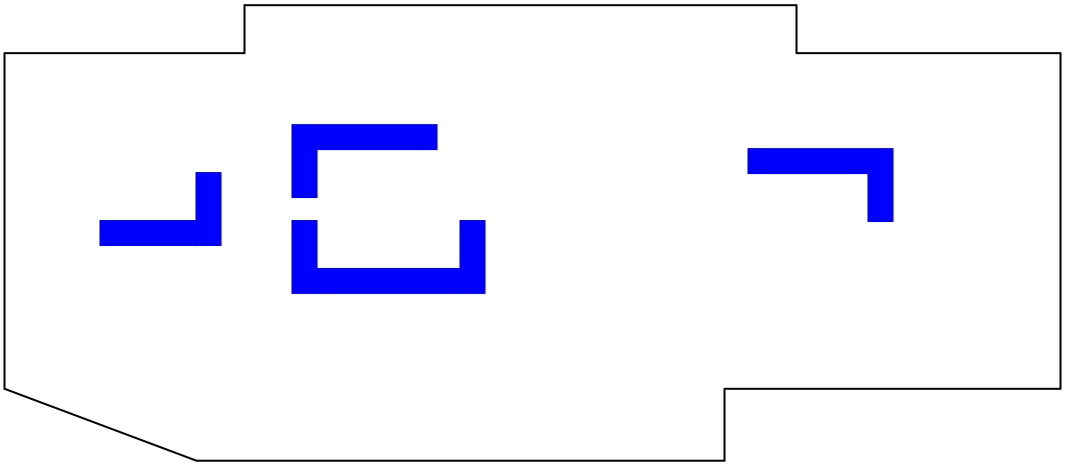

Figure 6. Shear wall layout for the 39th floor

Non-Typical Shear Wall Elevations

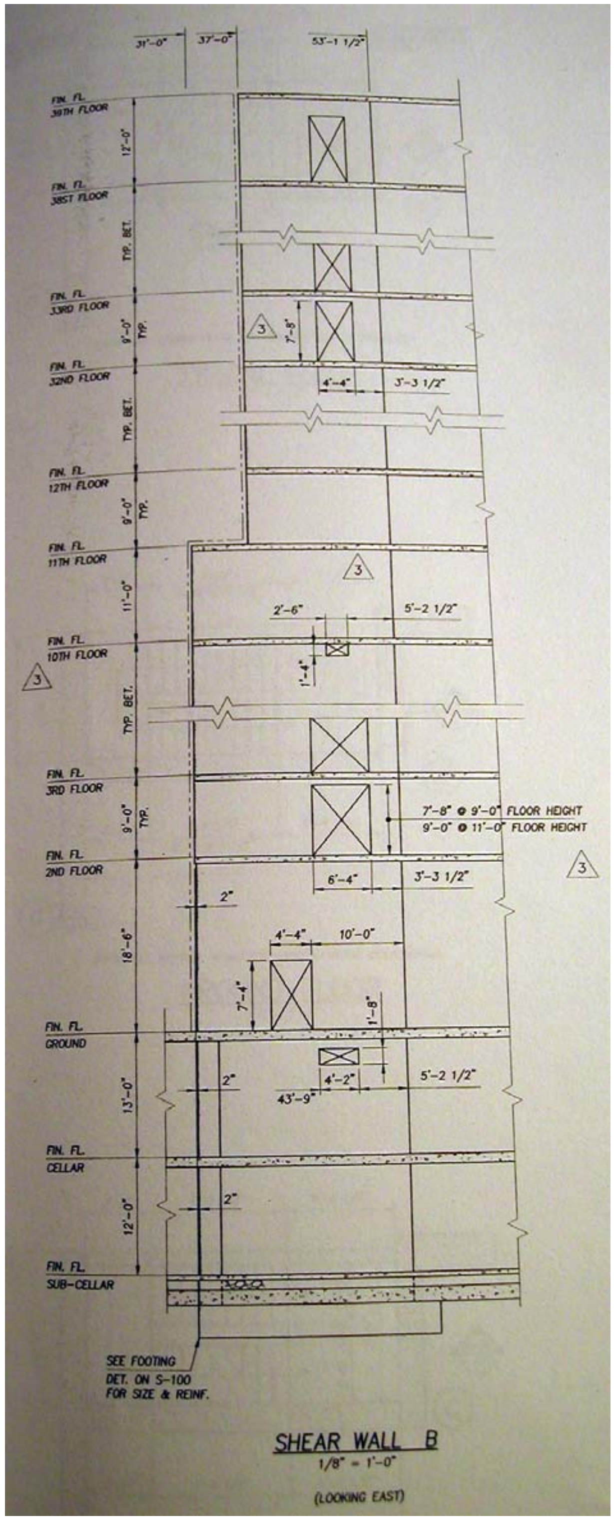

Figure 7. Elevation of shear wall B

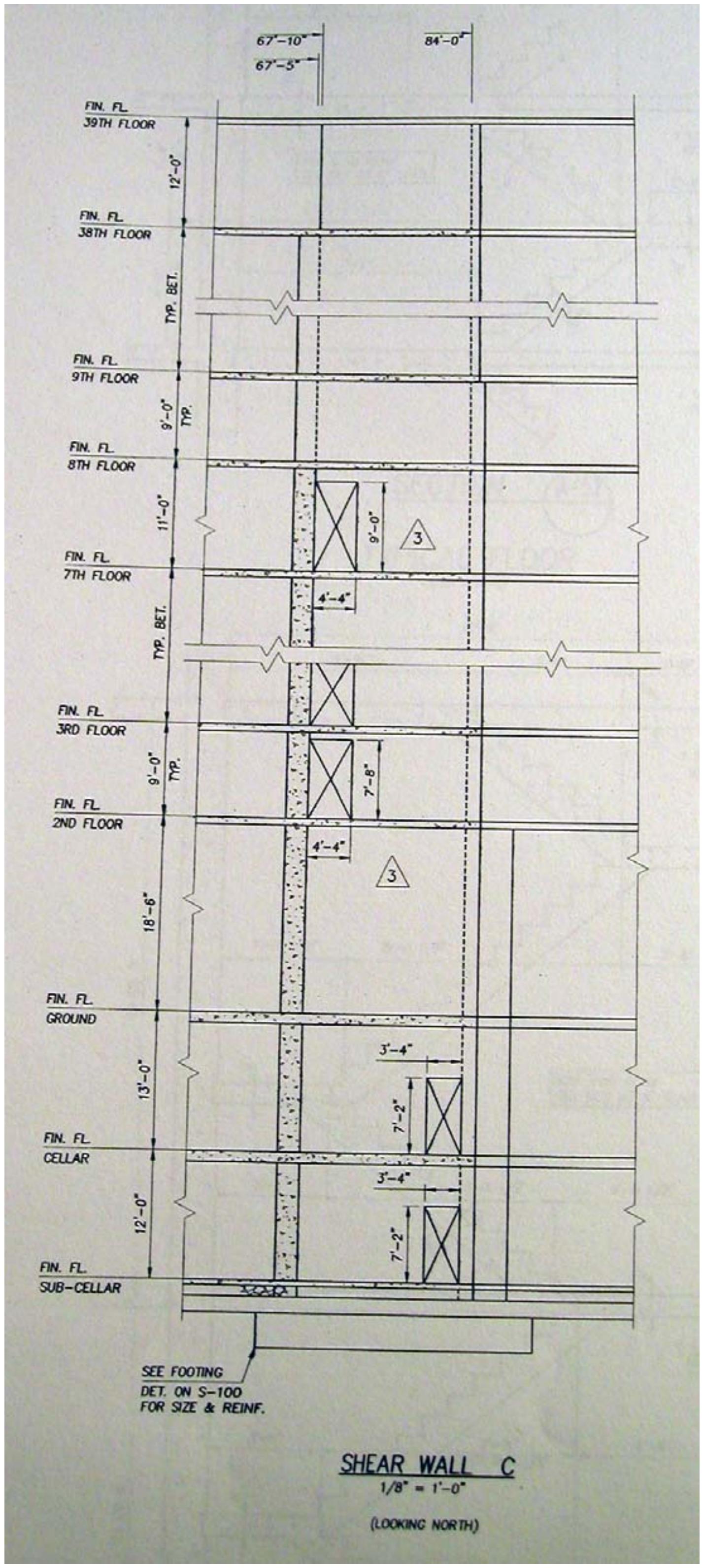

Figure 8. Elevation of shear wall C

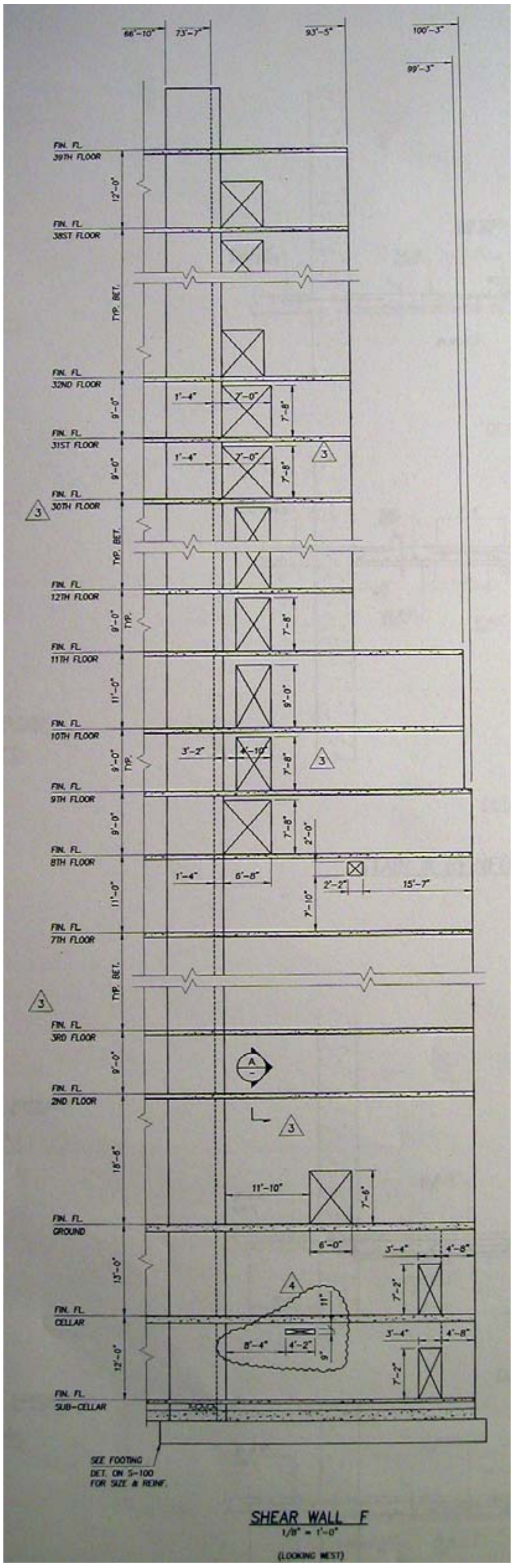

Figure 9. Elevation of shear wall F

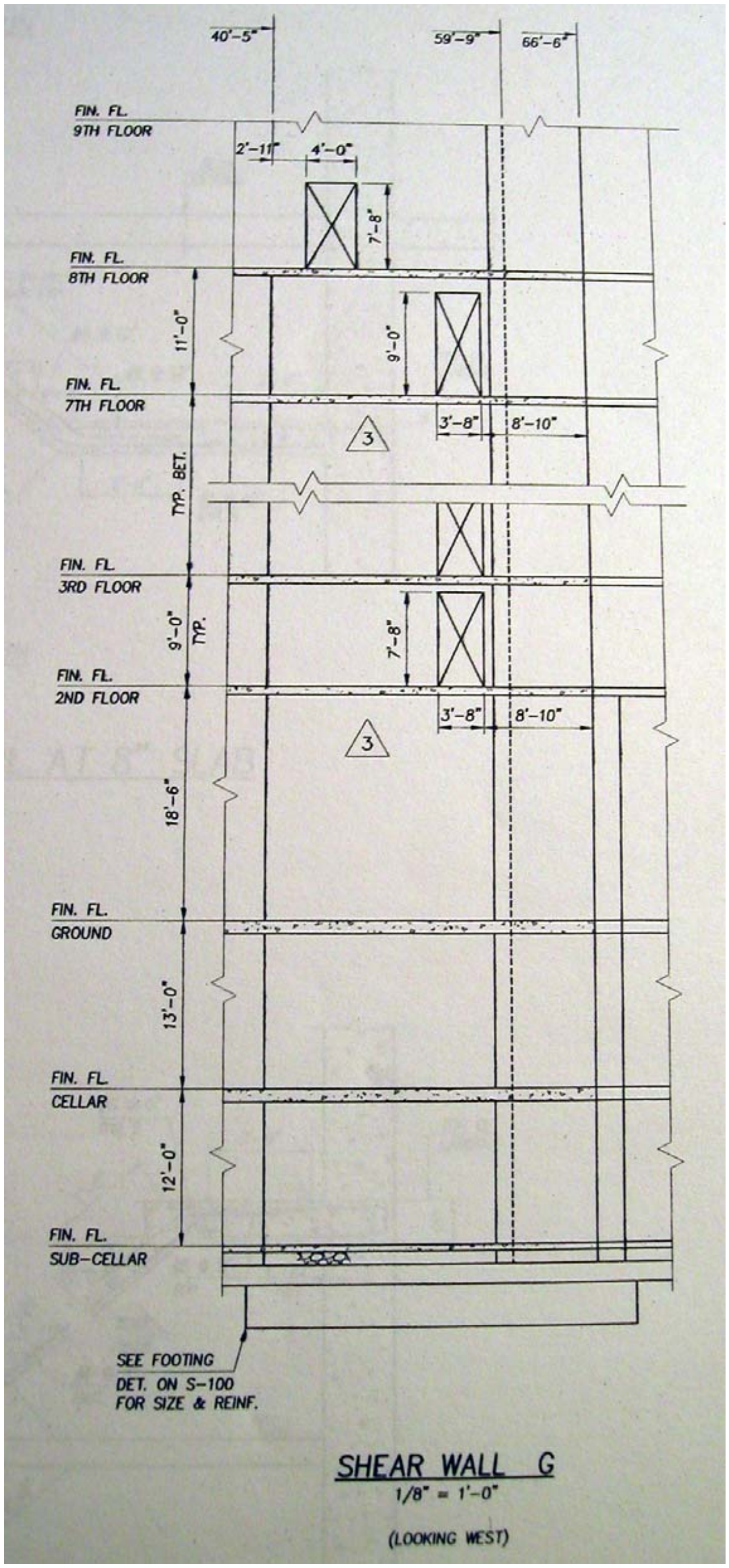

Figure 9. Elevation of shear wall G

Loads and Load Cases

The loads used in this analysis were computed in Technical Assignment #1. They were designed using ASCE 7-98 as referenced in the New York City Building Code. For reference, the figures provided are a summary of the lateral load design performed in Technical Assignment #1. As for the load cases used in this analysis, they will be taken from ACI 318-02 and consist of:

- 1.4D
- 1.2D + 1.6L
- 1.2D + 0.8W
- 1.2D + 1.0L + 1.6W
- 1.2D + 1.0L + 1.0E
- 0.9D + 1.6W
- 0.9D + 1.0E

Since the shear walls will also be taking a portion of the building's gravity load, the first two load cases must be considered. The remaining load cases must all be taken into account when considering the combination of gravity and lateral load forces on a building. Of these remaining cases, the last two will be used in this analysis because of the smaller amount of dead load contributing to the design. This means there is not as much gravity load, which is needed to resist the overturning moment.

The diagrams on the following pages are a summary of the wind and seismic lateral loads which were designed in Technical Assignment #1 and will be used in this analysis of the lateral bracing system of The Helena. Looking at the diagrams shows that wind forces will be the controlling factor in both the East-West and North-South directions except at the roof where the high seismic load will be a controlling factor. Because of this, the load case of 0.9D + 1.6W will be the controlling case. Calculations were done through an Excel spreadsheet and can be provided upon request.

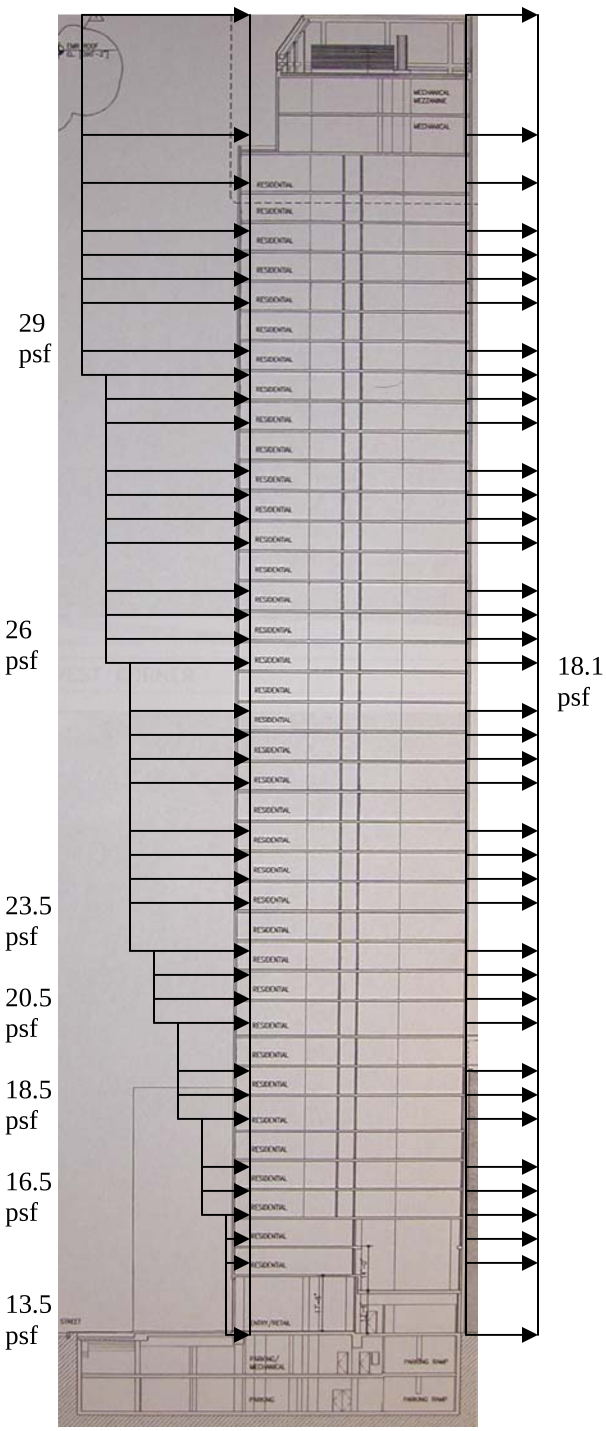

Figure 10. The Windward/Leeward Pressure Diagram for the N-S Direction

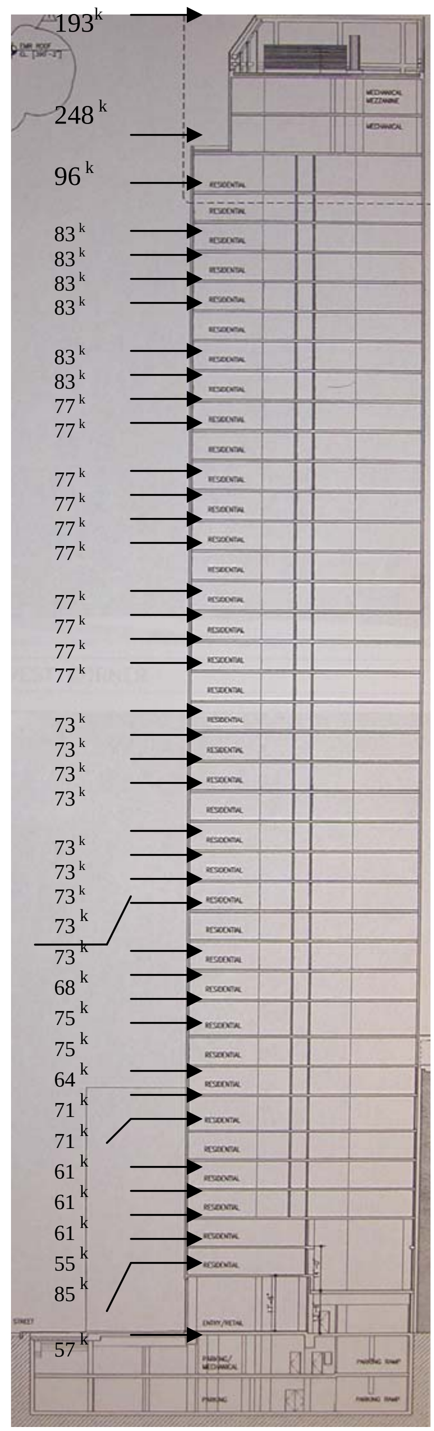

Figure 11. The Story Shear Forces for the N-S Direction

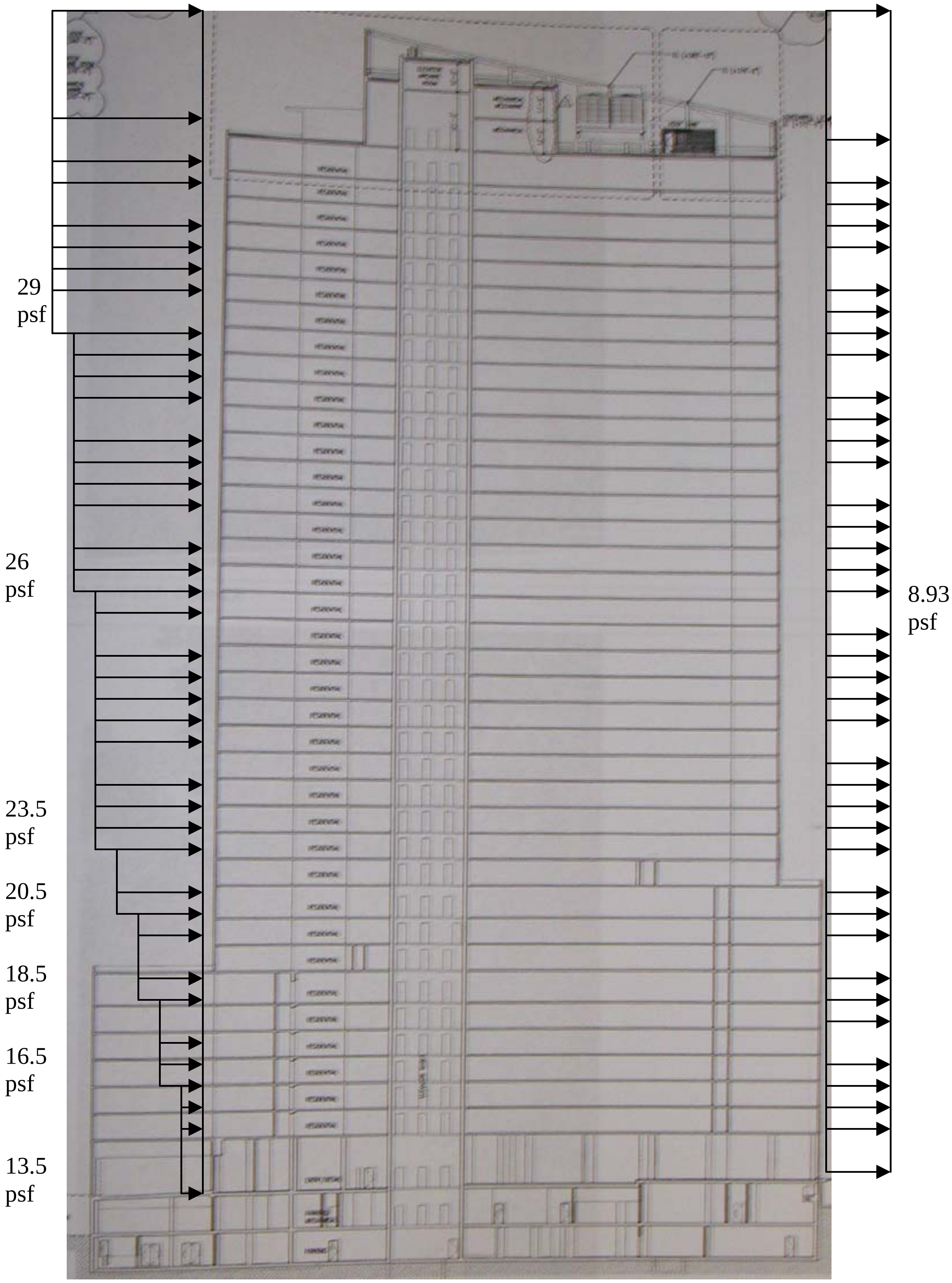

Figure 12. The Windward/Leeward Pressure Diagram for the E-W Direction

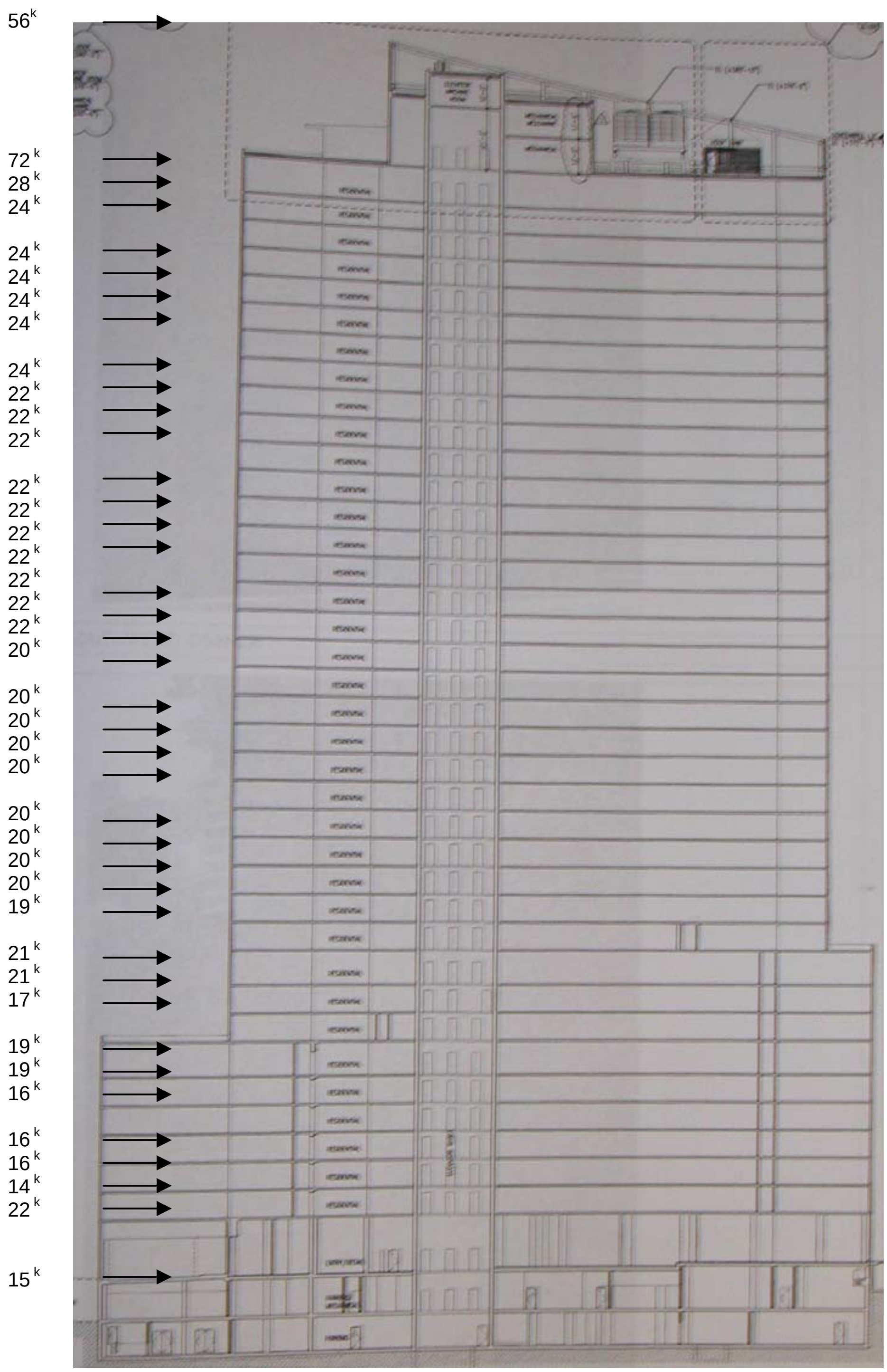

Figure 13. The Story Shear Forces for the E-W Direction

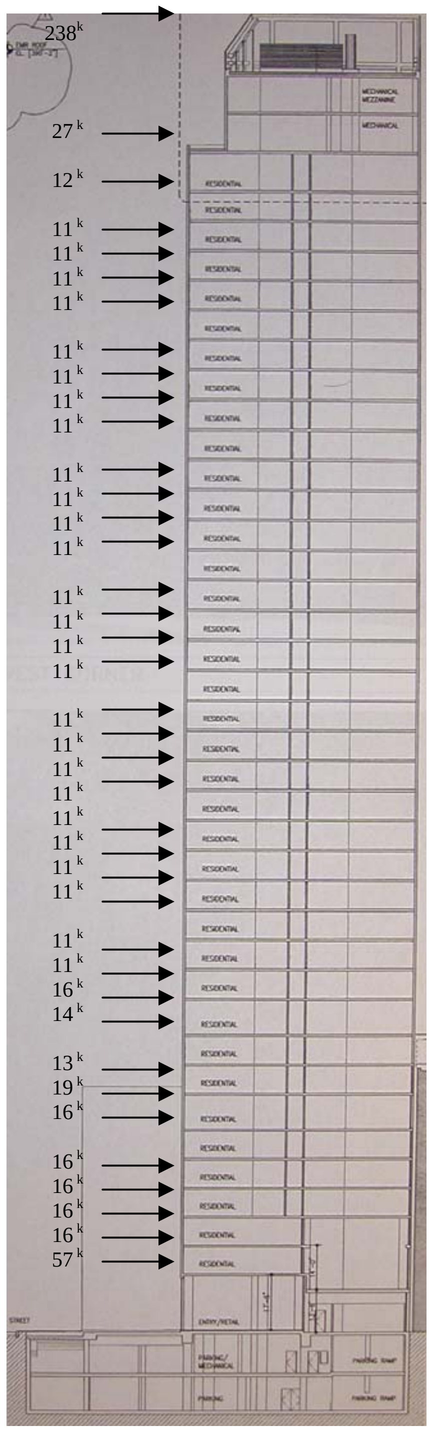

Figure 14. Seismic story forces

Distribution of Forces and Loads

The building as a whole will deflect which means each shear wall must deflect at the same magnitude. To accomplish this, I calculated the relative stiffness of each of the walls. A unit load was placed at the top of each wall to complete this. Once this was done, I calculated the center of rigidity of the walls to find out whether the center of lateral load was different from that of the center of rigidity which could cause torsional moment in the walls. After calculating the center of rigidity for the floors, it was noticed that the center of rigidity was quite comparable to the center of lateral load of the building and torsional forces would have an effect on some of the walls which were further from the center of the building. The center of rigidity of the building changed only slightly when calculated at several different levels. For an exact analysis, this would need to be calculated at all levels to determine the exact location because of the effect that this eccentricity would have on the torsional forces on the shear walls. The torsional moments would need to be calculated in both directions, parallel to the force and perpendicular. These forces can be both helpful and hurtful to the design of the walls. Depending on the wall’s location relative to the location of the center of rigidity, the torsional force can either help or hurt the wall’s design. The force created by the torsion can provide a greater resisting force to the overturning moment or it can act in the same direction as the moment, creating the need to design the wall to resist a greater overturning moment. Almost all of the wall deflections were controlled by flexure meaning the relative stiffness would be different at each level. To save time, this was only calculated at a few levels; an exact analysis would require the relative stiffness to be calculated at each floor because of the changing dimensions of the walls. For simplicity, some of the walls were treated to be solid when in fact they had doorways through them on some floors. This could create the need to use link beams to help both sides of the wall deflect as one. It also weakens the wall and will cause more deflection to occur.

Conclusion

From an investigation of the foundation system, it is evident that some of the walls will create an overturning moment on the foundations which is resisted by using rock anchors. From reviewing the loads and deflections on the walls, it is seen that the column and slab, acting as a rigid diaphragm, will carry some of the lateral load. The positioning of the shear walls and columns allows for them to act as a frame and work together to resist more of the lateral force and reduce the amount of deflection on each individual member. In addition to this reducing the deflections, the torsional forces on the walls will, in some cases, aid in the resistance to the overturning moment placed on the walls. This depends on where the wall is with relation to the center of rigidity of the shear wall layout and also how far the wall is from the center of rigidity.