# 35 WEST 21ST STREET NEW YORK, NY


## TECHNICAL REPORT
## 1

DANIEL DONECKER
STRUCTURAL OPTION
FACULTY CONSULTAN: DR. THOMAS BOOTHBY
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# Executive summary

The goal of this report is to review structural concepts and the existing conditions of the structure using building codes and Engineering standards. Analysis was completed on typical framing elements such as structural slabs and columns, along with the lateral loads imposed on the building due to seismic and wind forces.

35 West 21st Street is composed of two towers, one 15 stories, and the other 8 stories above grade. The gravity system is comprised of two way flat plate concrete slabs with no beams or drop panels supported by concrete columns which transfer there load down to spread footings beneath the basement slab. The lateral system consists of multiple shear walls which transfer there load down to mat foundations below the basement slab. On the eastern side of the 15 story tower, bed rock is located about 50 feet below grade. Therefore, footings sit on top of mini caissons which go down to bed rock

Lateral loads were determined using ASCE 7-05. Method 2 was used for the wind loads while the Equivalent Lateral Force procedure was used for the seismic loads. It was determined the seismic base shear calculated matched that of the design base shear within 5%, while the wind pressures on the building were significantly different than the design pressures. This difference can be attributed to the different codes used in the analysis and design. The design engineers used the Building Code of the City of New York, while the analysis used the provisions of ASCE 7-05. The Building Code of the City of New York uses a much more simplified approach to wind than ASCE 7-05, and therefore may not represent the actual pressures predicted by ASCE 7-05.

The gravity load analysis was completed using loads from IBC 2006 and design procedures of ACI 318-05. Live load reduction was not used in the analysis, however it was concluded that the design of the two way flat plate slab and columns are conservative and meet the requirements of the codes and standards used. Discrepancies in calculations are due to different assumptions made and the use of different codes than those used in design. Calculations and general assumptions are included in an Appendix at the end of the report.

# Table of Contents

# Introduction

35 West 21st Street is shaped by the surrounding buildings and its site. With adjacent 4-12 story buildings, the plan takes on a T-shape to maximize the footprint. The stem of the T-shape is an eight story residential tower facing the north, while the top of the T-shape is a fifteen story residential tower facing the south with retail space on the ground. Over 162,000 sq. feet of residential and retail space is provided.

35 West 21st Street is located in the Flatiron District within the Ladies' Mile Historic District. The area is zoned as C6-4A which allows for commercial, light manufacturing, and residential construction. The predominant historical requirements of Ladies' Mile consist of street walls a minimum of 60 feet tall that are in character with the surrounding area. Therefore, the building is has a classic stone façade with infill glass windows.

The columns of superstructure run from foundation to the top of the building with no transfers throughout the building. The columns are arranged in a semi regular pattern where most bays are rectangular in plan. The arrangement of columns allows for open residential and retail floor plans while a two way flat plate concrete floor system allows for high ceilings with only a typical 9'-8" floor to floor height. The top residential units have large personal balconies which overlook the surrounding city and allow for a spacious outdoor room in crowded New York City.

# Structural Systems Overview

## Floor System

35 West 21st Street is a typical reinforced concrete residential structure. The floor system is a two way flat plate slab without drop panels or beams. Typical residential floors are 8 inches thick with typical reinforcement of #5 deformed bars at 12 inches on center bottom bars (each way) and #5 deformed bars at 12 inches on center Middle Strip top bars. Column Strip top bars vary according to span lengths. In areas of high shear, slab supports also have stud rails to help prevent punch through shear. Typical columns are gravity only, and run the entire height of the building without transfers. On the fifteenth floor, columns lining the exterior balconies are transferred to the 14" slab and then transferred to nearby columns that go down to the foundations. Typical columns are 16"x18" with 8-#7 longitudinal bars and #3 ties at 12 inches on center. Minimum concrete compressive strength is 5 ksi for slabs above ground, and 5.95 ksi for columns. The slab also provides a two hour fire rating.

## Basement

The basement floor is a slab on grade reinforced with 6" WWF 6x6 – W2.0xW2.0. Typical slab on grade thickness is 6".

## Roof system

The roof slab is 12 inches thick with typical reinforcing like that on all the residential floors. Cooling towers sit on dunnage that consists of 16"x16" concrete piers and galvanized W10x33 steel beams. The remaining mechanical equipment including elevator machines are housed in the bulk head which consists of shear wall 16 and three transfer columns. Shear The concrete piers and columns are transferred through the 12" slab and into columns below that continue to the foundation.

**Lateral System**

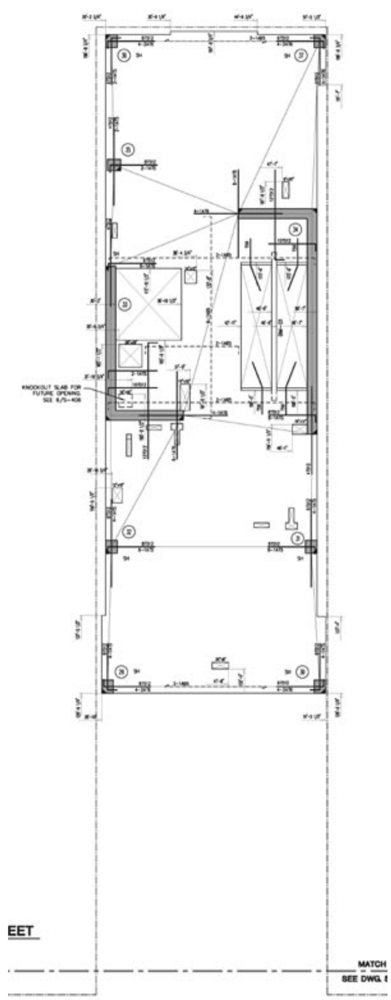
The lateral system of 35 West 21st Street is comprised of shear walls in both the North-South and East-West directions of the building. The two towers of the building are built integrally with each other through the two way slab on the basement, ground and second floor. However, at the second floor, the 15 story south tower steps back to allow for an outdoor courtyard, thus breaking the connection between the two towers. Because the connection of the two towers only exists on the first two floors, the towers' lateral systems were designed separately from each other. The assumption that the two buildings act separately and thus do not transfer any torsional moment between the two lateral systems will be investigated more closely in following technical reports. As for this technical report, it is assumed that the two buildings act separately. Typical shear walls are 1'-0" wide and longitudinal reinforcement ranges from #10 at 12" on center at the base of the shear walls to #4 at 12" on center at the top of the building. Horizontal shear reinforcement typically consists of #4 at 12" on center closed loop bars.

**Foundation**

The foundation system consists of spread footings for typical concrete columns and large mat foundations for shear walls. On the east side of the building, 240 ton caissons spread loads from the footings to the bedrock below. The caissons are at a minimum drilled 9'-0" into bedrock and are typically 12 inches in diameter.

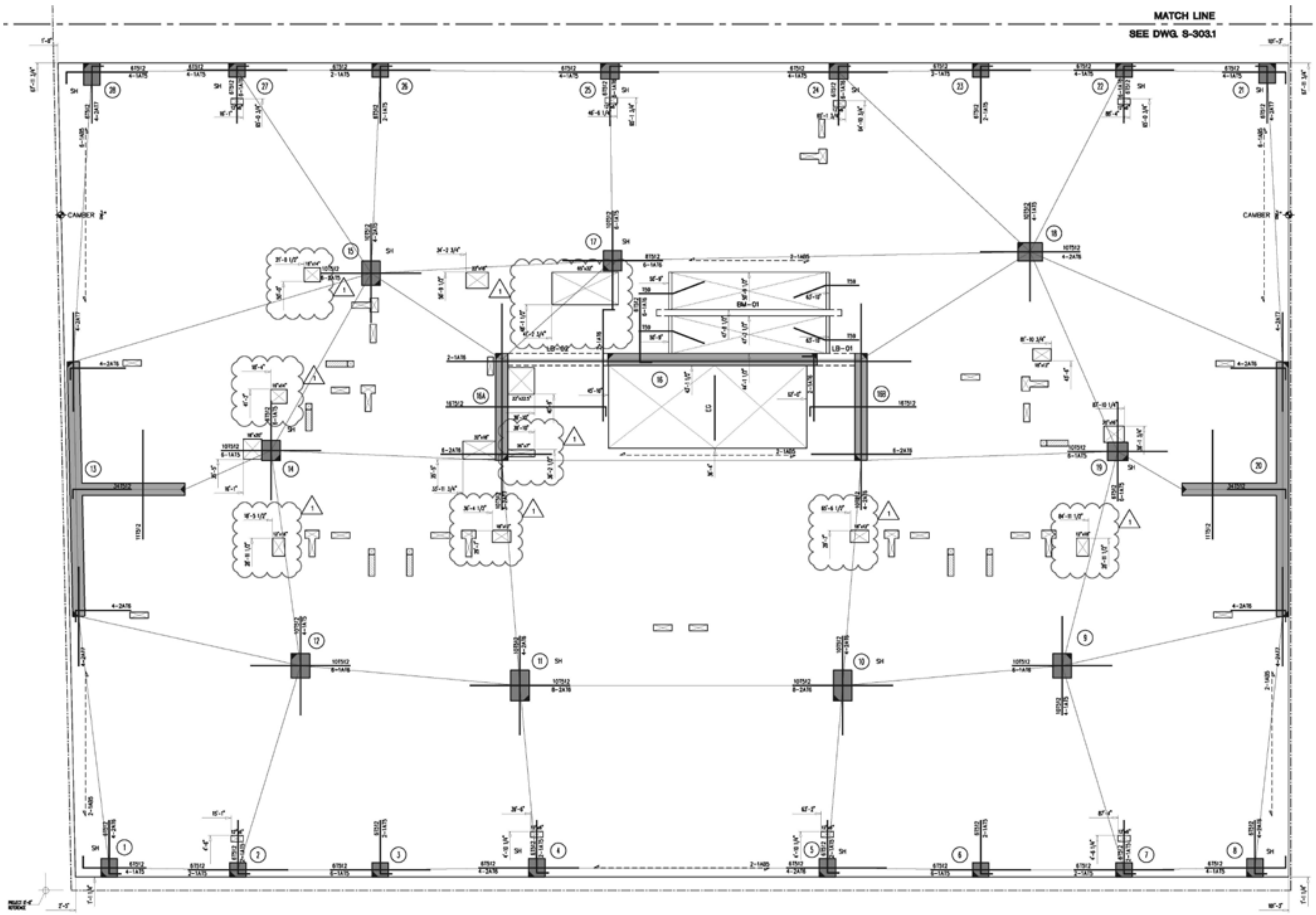
# Typical Floor Framing Plan

Typicall framing plan (level 3-14). Most columns follow the same pattern the whole way through the building. All residential floors except for the 15th floor follow the same floor plan. On the 15th floor the building steps back to allow for large balcony space on the top floor.



8 Story Tower

Due to the small width of the tower, columns are able to be placed only at the exterior walls of the structure. This allows for completely open spaces, however the two way slab system does not meet the limitations of ACI 318-05 Chapter 13 for the direct design method.

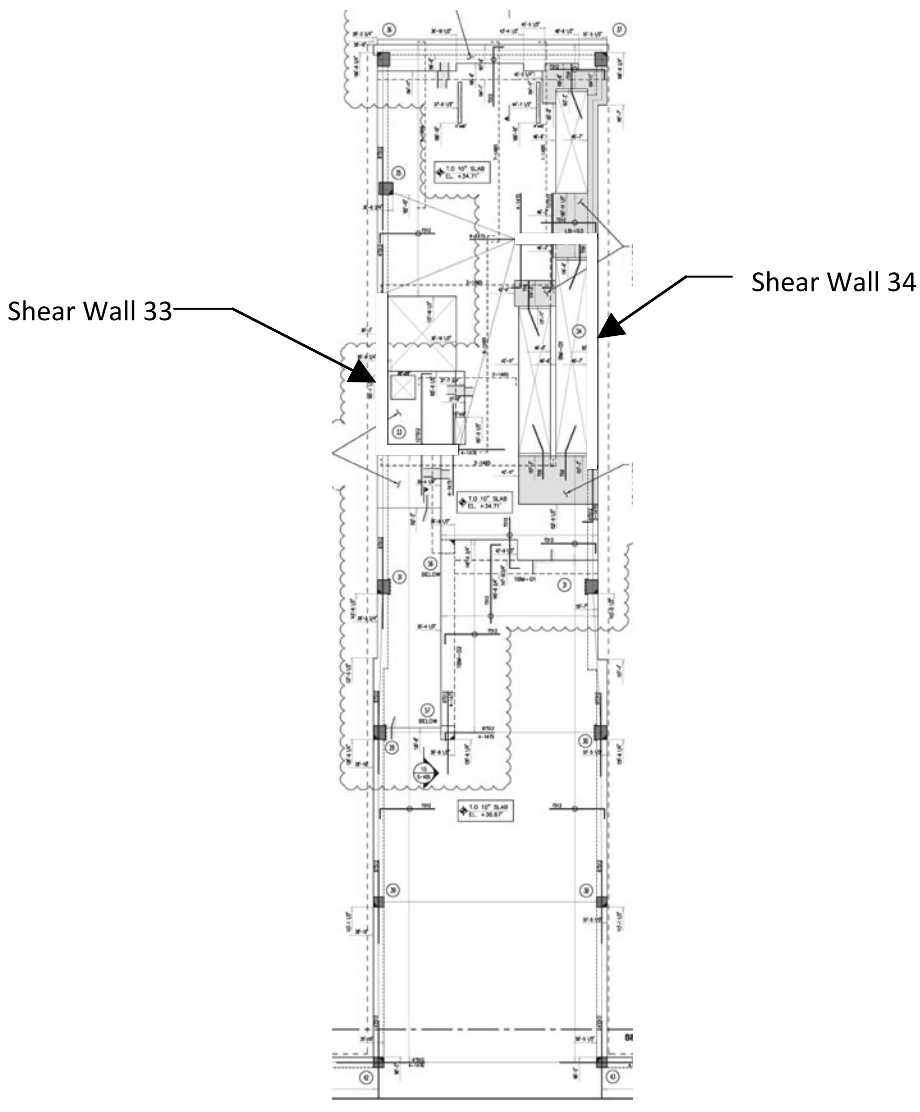



15 story tower

Bays do not follow a typical pattern or spacing, however most bays have a semi-regular shape that meets the design requirements of ACI 318-05 Chapter 13 for the direct design method. Columns are spaced to optimize both the retail and residential areas.

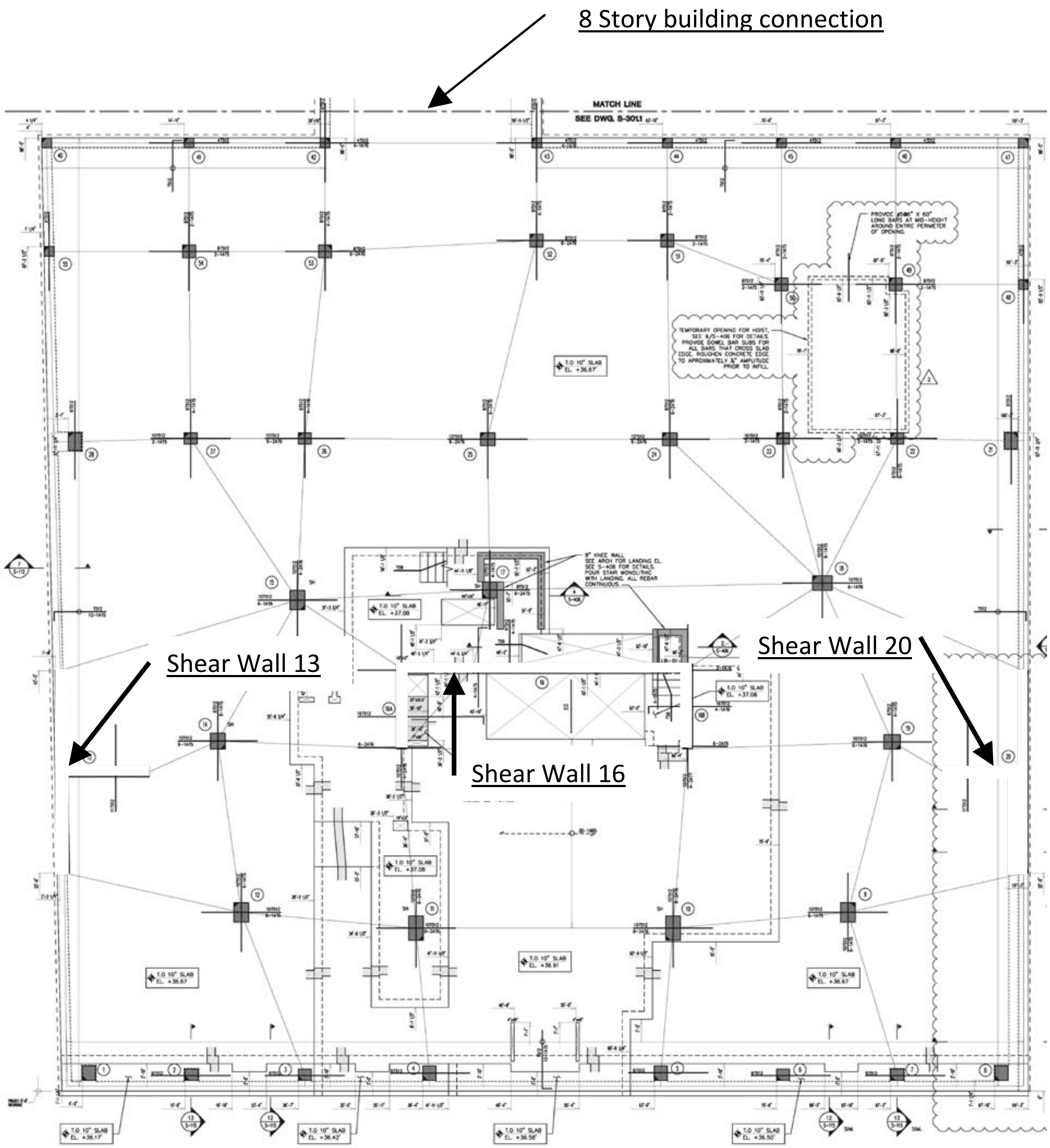
# Lateral System

The lateral load resisting system consists of shear walls that all run the entire height of the building. The two towers were analyzed separately because continuity of the floor diaphragm between the two is only maintained on the ground and second floor. The lateral resisting planes of the shear walls are in both the major axis of the structure (North-South and East-West).




Shear wall layout for 8 story tower

(Ground Floor Plan)




Shear Wall layout for 15 story tower

(Ground Floor Plan)

# Codes and Materials

**Codes used in original design:**

- Building Code of the City of New York, Including latest amendments (N.Y.C. Code)
- American Institute of Steel Construction "Specification for structural steel buildings – Allowable Stress Design and Plastic Design", June 1, 1989 ("AISC Specification"). As modified by subchapter 10 article 6 of the NYC Building Code.
- American Concrete Institute "Building Code Requirements for Structural Concrete" ACI 318-99 ("ACI") as modified by subchapter 10 article 5 of the NYC Building Code.
- American Concrete Institute "Building Code Requirements for Masonry Structures" ACI 530-99 ("ACI 530") as modified by reference standard RS 10 – 18 of the NYC Building Code.

**Codes and standards used for technical report 1:**

- American Society for Civil Engineers – "Minimum Design Loads for Buildings and other Structures" ASCE 7-05.
- American Concrete Institute "Building Code Requirements for Structural Concrete" ACI 318-05
- International Building Code – IBC 2006
- American Institute of Steel Construction "Specification for Structural Steel Buildings" 13th Edition 2005

**Material Summary:**

Structural Steel

- All rolled shapes ……………………………………………………………………………ASTM A992 GRADE 50

Cast-in-place Concrete

- Foundations………………………………………………………………………………………..5 ksi Normal wt.
- Slabs on Ground………………………………………………………………………………….3 ksi Normal wt.
- Formed Slabs……………………………………………………………………………………….5 ksi Normal wt.
- Columns…………………………………………………………………………………………….5.95 ksi Normal wt.
- Walls…………………………………………………………………………………………………….5 ksi Normal wt.

Reinforcement

- Deformed Bars……………………………………………………………………………ASTM A615, GRADE 60
- Welded Wire Fabric…………………………………………………………………………………….ASTM A185

# Building Load Summary

**Gravity Loads:**

The loads listed below are from IBC 2006 and ASCE 7-05. They agree with the loads selected for design by the original Engineer.

**Dead Loads:**

- Reinforced Concrete……150 PCF
- M.E.P./Partitions……15 PSF
- Roof (Uniform)……20 PSF
- Roof (Mechanical Equipment)……50 kips

**Live Loads (Per IBC 2006):**

- Lobbies……100 PSF
- Retail……100 PSF
- Residential……40 PSF
- First Floor Corridors……100 PSF
- Corridors Above First Floor……80 PSF
- Stairs……100 PSF

**Wind Loads:**

Wind loads were calculated using Method Two of chapter 6 in ASCE7-05. These wind loads significantly differ from those used by the design engineer. One reason for this is that The NYC Building Code uses a very simple approach to wind by assigning pressures based only on building height. In ASCE 7-05, many other factors are taken into consideration. For example, approximate building period, building dimensions, and exposure categories. The calculations differ not because of a mistake made, but because of the code used to determine the wind pressures.

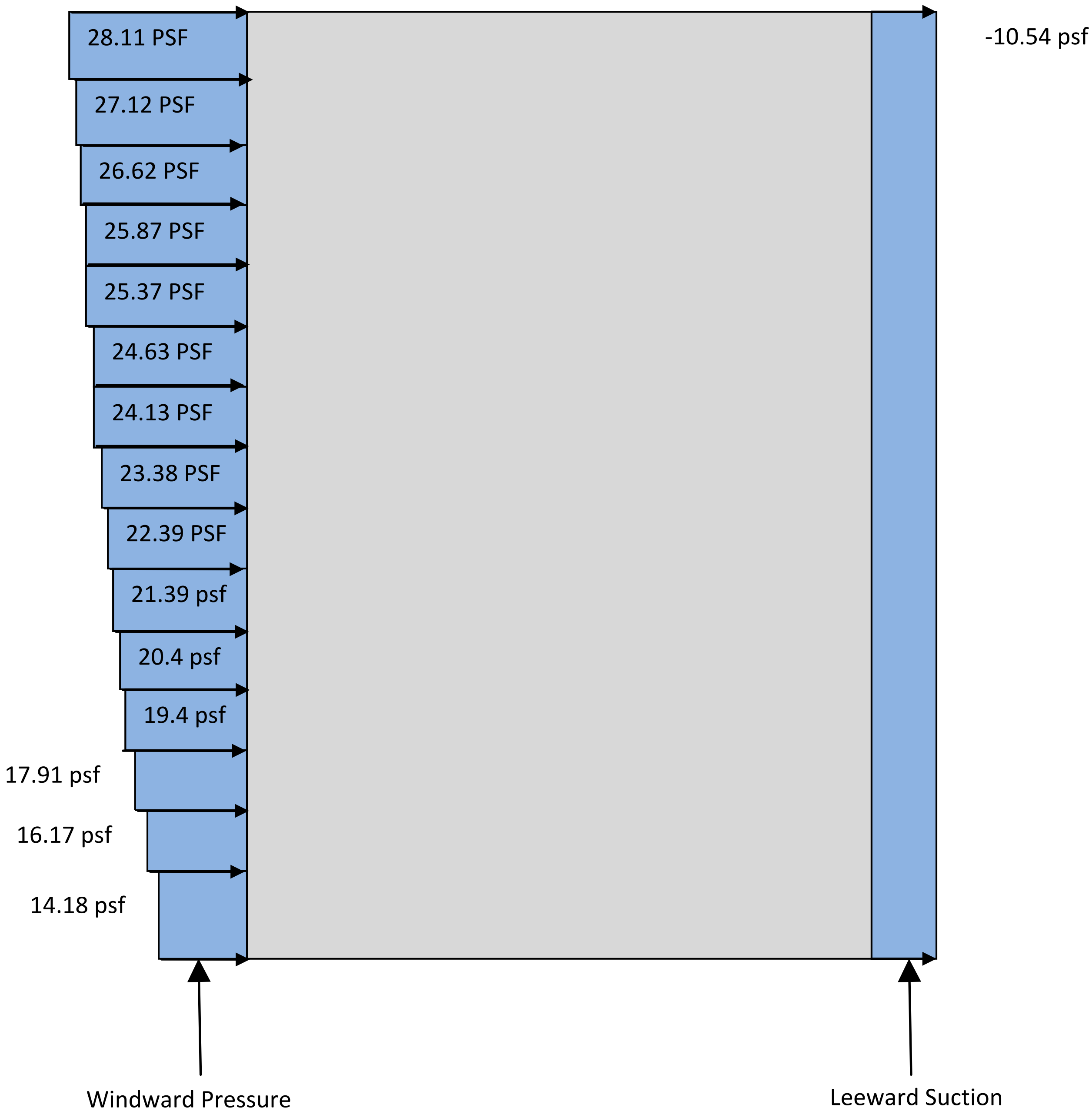
***East/West Wind load calculation (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 0.57 | 1.00 | 0.85 | 110 | 1.00 | 15.01 | 1.181 | 0.80 | **14.18** |
| 3 | 9.67 | 23.67 | 0.65 | 1.00 | 0.85 | 110 | 1.00 | 17.11 | 1.181 | 0.80 | **16.17** |
| 4 | 9.67 | 33.34 | 0.72 | 1.00 | 0.85 | 110 | 1.00 | 18.96 | 1.181 | 0.80 | **17.91** |
| 5 | 9.67 | 43.01 | 0.78 | 1.00 | 0.85 | 110 | 1.00 | 20.54 | 1.181 | 0.80 | **19.40** |
| 6 | 9.67 | 52.68 | 0.82 | 1.00 | 0.85 | 110 | 1.00 | 21.59 | 1.181 | 0.80 | **20.40** |
| 7 | 9.67 | 62.35 | 0.86 | 1.00 | 0.85 | 110 | 1.00 | 22.64 | 1.181 | 0.80 | **21.39** |
| 8 | 9.67 | 72.02 | 0.90 | 1.00 | 0.85 | 110 | 1.00 | 23.70 | 1.181 | 0.80 | **22.39** |
| 9 | 9.67 | 81.69 | 0.94 | 1.00 | 0.85 | 110 | 1.00 | 24.75 | 1.181 | 0.80 | **23.38** |
| 10 | 9.67 | 91.36 | 0.97 | 1.00 | 0.85 | 110 | 1.00 | 25.54 | 1.181 | 0.80 | **24.13** |
| 11 | 9.67 | 101.03 | 0.99 | 1.00 | 0.85 | 110 | 1.00 | 26.07 | 1.181 | 0.80 | **24.63** |
| 12 | 9.67 | 110.70 | 1.02 | 1.00 | 0.85 | 110 | 1.00 | 26.86 | 1.181 | 0.80 | **25.37** |
| 13 | 9.67 | 120.37 | 1.04 | 1.00 | 0.85 | 110 | 1.00 | 27.38 | 1.181 | 0.80 | **25.87** |
| 14 | 9.67 | 130.04 | 1.07 | 1.00 | 0.85 | 110 | 1.00 | 28.17 | 1.181 | 0.80 | **26.62** |
| 15 | 10.67 | 140.71 | 1.09 | 1.00 | 0.85 | 110 | 1.00 | 28.70 | 1.181 | 0.80 | **27.12** |
| Ro | 13.33 | 154.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | 0.80 | **28.11** |

***East/West Wind load calculation (Leeward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 3 | 9.67 | 23.67 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 4 | 9.67 | 33.34 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 5 | 9.67 | 43.01 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 6 | 9.67 | 52.68 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 7 | 9.67 | 62.35 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 8 | 9.67 | 72.02 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 9 | 9.67 | 81.69 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 10 | 9.67 | 91.36 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 11 | 9.67 | 101.03 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 12 | 9.67 | 110.70 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 13 | 9.67 | 120.37 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 14 | 9.67 | 130.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 15 | 10.67 | 140.71 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |
| 16 | 13.33 | 154.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.181 | -0.30 | **-10.54** |

**East/West Wind Load Diagram on 15 story tower**



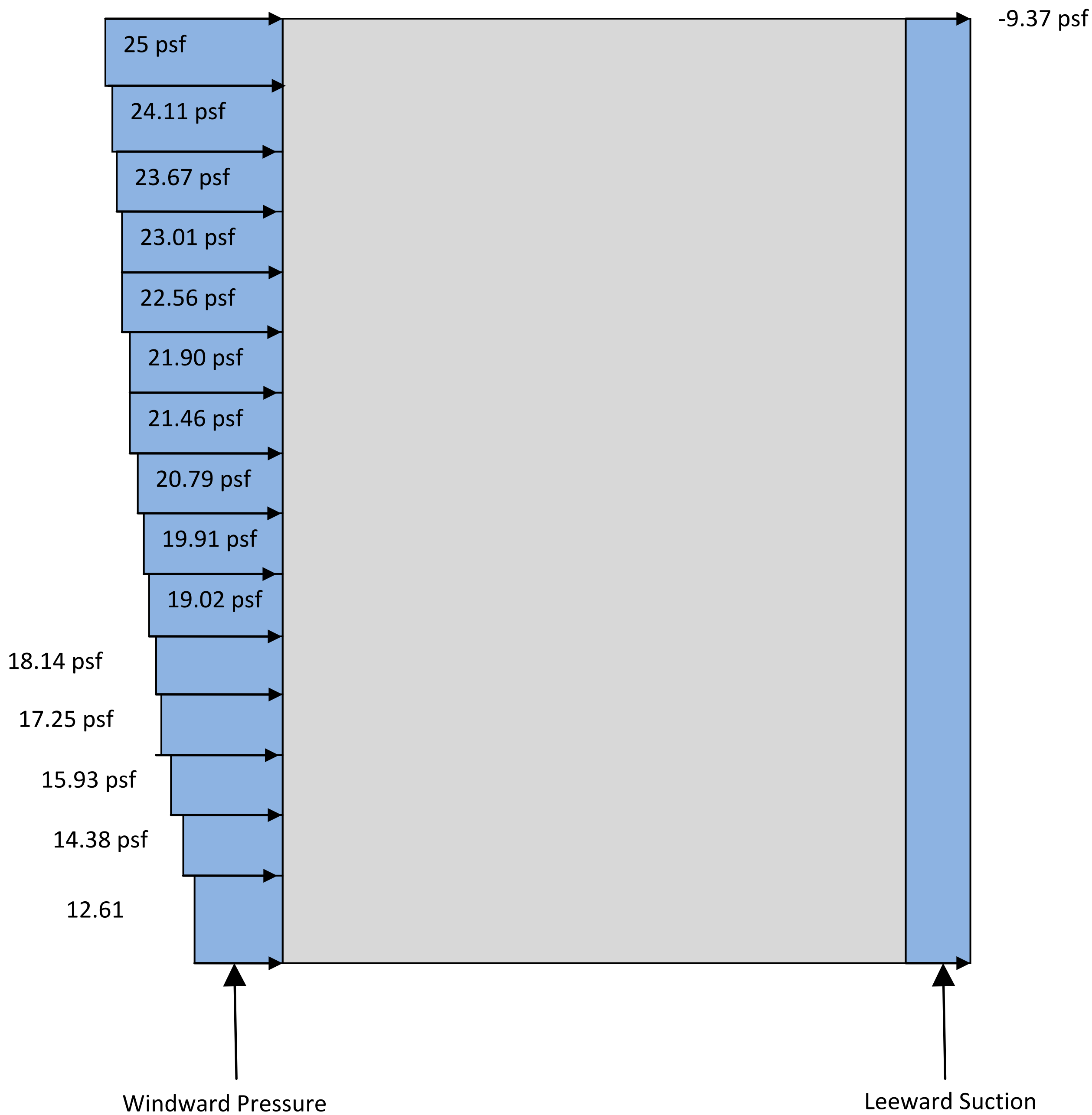
***North/South Wind Load Calc. (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 0.57 | 1.00 | 0.85 | 110 | 1.00 | 15.01 | 1.050 | 0.80 | **12.61** |
| 3 | 9.67 | 23.67 | 0.65 | 1.00 | 0.85 | 110 | 1.00 | 17.11 | 1.050 | 0.80 | **14.38** |
| 4 | 9.67 | 33.34 | 0.72 | 1.00 | 0.85 | 110 | 1.00 | 18.96 | 1.050 | 0.80 | **15.93** |
| 5 | 9.67 | 43.01 | 0.78 | 1.00 | 0.85 | 110 | 1.00 | 20.54 | 1.050 | 0.80 | **17.25** |
| 6 | 9.67 | 52.68 | 0.82 | 1.00 | 0.85 | 110 | 1.00 | 21.59 | 1.050 | 0.80 | **18.14** |
| 7 | 9.67 | 62.35 | 0.86 | 1.00 | 0.85 | 110 | 1.00 | 22.64 | 1.050 | 0.80 | **19.02** |
| 8 | 9.67 | 72.02 | 0.90 | 1.00 | 0.85 | 110 | 1.00 | 23.70 | 1.050 | 0.80 | **19.91** |
| 9 | 9.67 | 81.69 | 0.94 | 1.00 | 0.85 | 110 | 1.00 | 24.75 | 1.050 | 0.80 | **20.79** |
| 10 | 9.67 | 91.36 | 0.97 | 1.00 | 0.85 | 110 | 1.00 | 25.54 | 1.050 | 0.80 | **21.46** |
| 11 | 9.67 | 101.03 | 0.99 | 1.00 | 0.85 | 110 | 1.00 | 26.07 | 1.050 | 0.80 | **21.90** |
| 12 | 9.67 | 110.70 | 1.02 | 1.00 | 0.85 | 110 | 1.00 | 26.86 | 1.050 | 0.80 | **22.56** |
| 13 | 9.67 | 120.37 | 1.04 | 1.00 | 0.85 | 110 | 1.00 | 27.38 | 1.050 | 0.80 | **23.01** |
| 14 | 9.67 | 130.04 | 1.07 | 1.00 | 0.85 | 110 | 1.00 | 28.17 | 1.050 | 0.80 | **23.67** |
| 15 | 10.67 | 140.71 | 1.09 | 1.00 | 0.85 | 110 | 1.00 | 28.70 | 1.050 | 0.80 | **24.11** |
| 16 | 13.33 | 154.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | 0.80 | **25.00** |

***North/South Wind Load Calc. (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_h$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 3 | 9.67 | 23.67 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 4 | 9.67 | 33.34 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 5 | 9.67 | 43.01 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 6 | 9.67 | 52.68 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 7 | 9.67 | 62.35 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 8 | 9.67 | 72.02 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 9 | 9.67 | 81.69 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 10 | 9.67 | 91.36 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 11 | 9.67 | 101.03 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 12 | 9.67 | 110.70 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 13 | 9.67 | 120.37 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 14 | 9.67 | 130.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 15 | 10.67 | 140.71 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |
| 16 | 13.33 | 154.04 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.050 | -0.30 | **-9.37** |

**North/South Wind Load Diagram on 15 story tower**



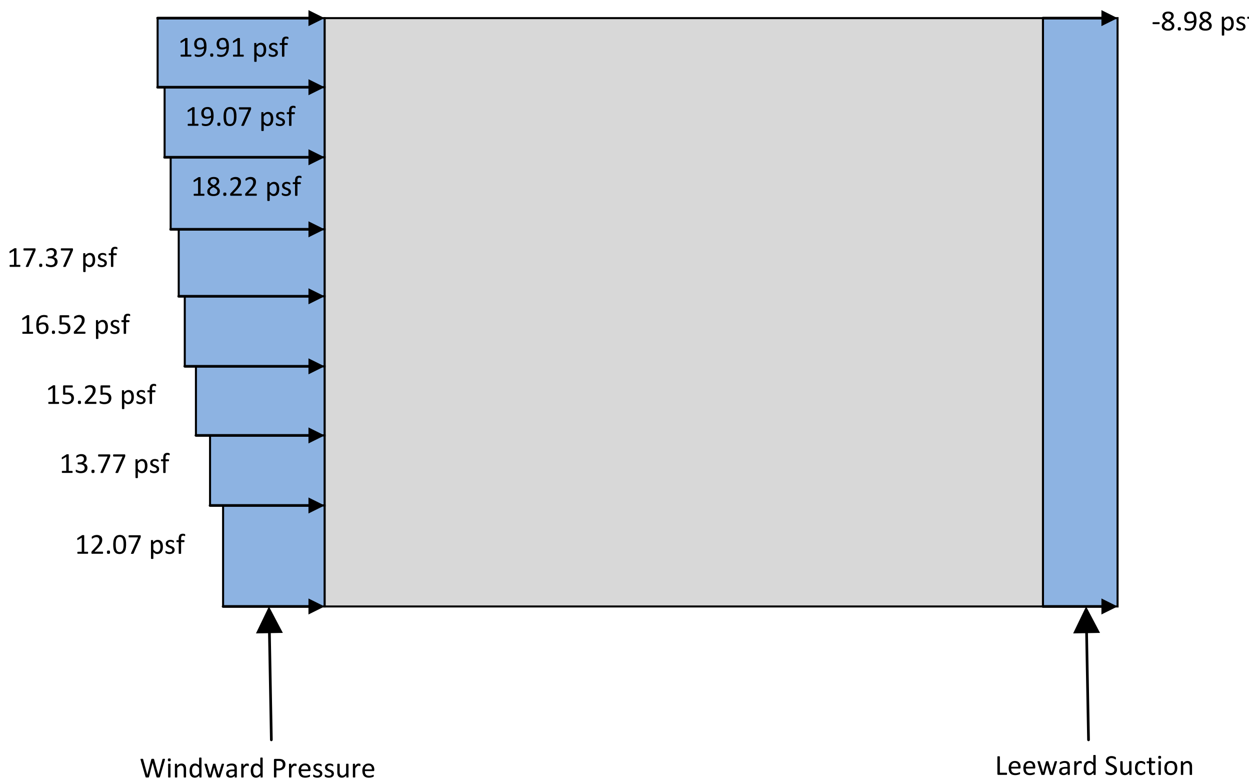
***East/West Wind load calculation (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 0.57 | 1.00 | 0.85 | 110 | 1.00 | 15.01 | 1.006 | 0.80 | **12.07** |
| 3 | 9.67 | 23.67 | 0.65 | 1.00 | 0.85 | 110 | 1.00 | 17.11 | 1.006 | 0.80 | **13.77** |
| 4 | 9.67 | 33.34 | 0.72 | 1.00 | 0.85 | 110 | 1.00 | 18.96 | 1.006 | 0.80 | **15.25** |
| 5 | 9.67 | 43.01 | 0.78 | 1.00 | 0.85 | 110 | 1.00 | 20.54 | 1.006 | 0.80 | **16.52** |
| 6 | 9.67 | 52.68 | 0.82 | 1.00 | 0.85 | 110 | 1.00 | 21.59 | 1.006 | 0.80 | **17.37** |
| 7 | 9.67 | 62.35 | 0.86 | 1.00 | 0.85 | 110 | 1.00 | 22.64 | 1.006 | 0.80 | **18.22** |
| 8 | 9.67 | 72.02 | 0.90 | 1.00 | 0.85 | 110 | 1.00 | 23.70 | 1.006 | 0.80 | **19.07** |
| roof | 9.67 | 81.69 | 0.94 | 1.00 | 0.85 | 110 | 1.00 | 24.75 | 1.006 | 0.80 | **19.91** |

***East/West Wind load calculation (Leeward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 3 | 9.67 | 23.67 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 4 | 9.67 | 33.34 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 5 | 9.67 | 43.01 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 6 | 9.67 | 52.68 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 7 | 9.67 | 62.35 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| 8 | 9.67 | 72.02 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |
| roof | 9.67 | 81.69 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 1.006 | -0.30 | **-8.98** |

**East/West Wind Loading Diagram on 8 story tower**



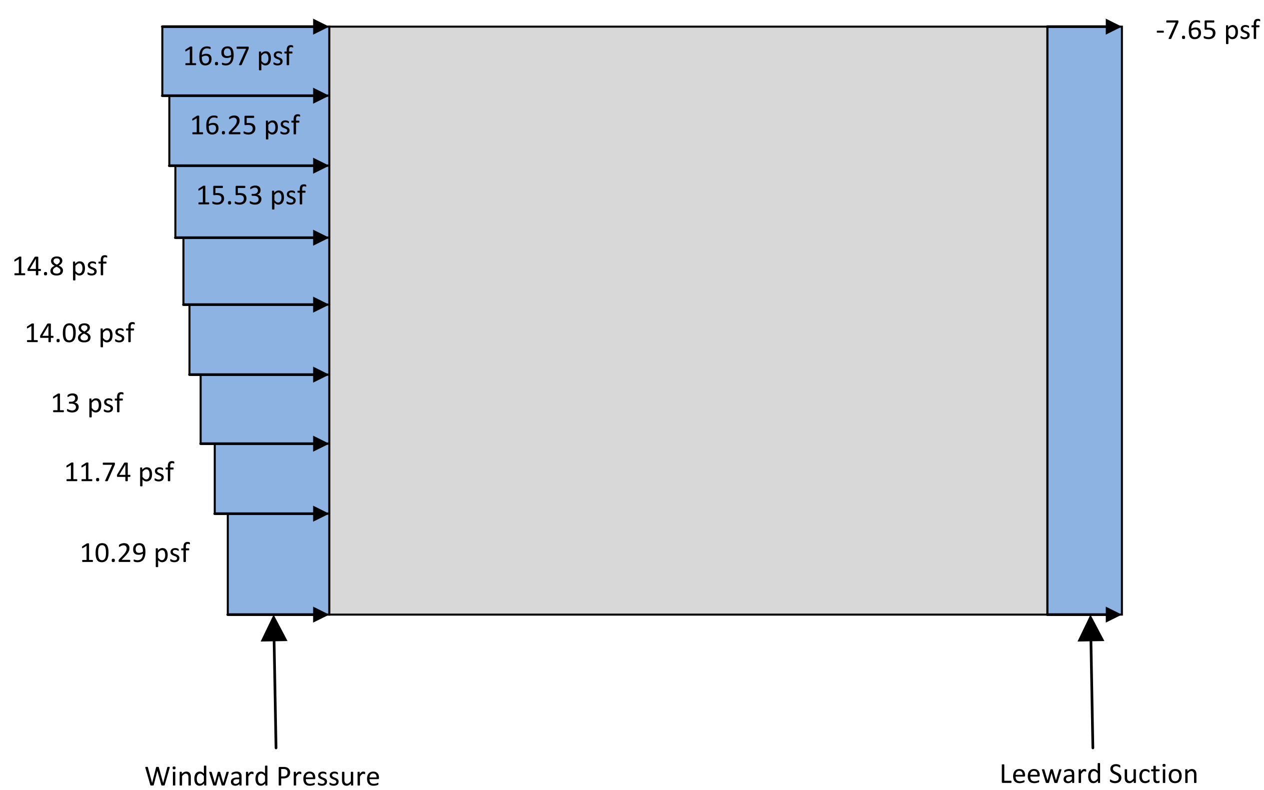

***North/South Wind Load Calc. (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_z$ | $G_f$ | $C_p$ | $\mathbf{p_z}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 0.57 | 1.00 | 0.85 | 110 | 1.00 | 15.01 | 0.857 | 0.80 | **10.29** |
| 3 | 9.67 | 23.67 | 0.65 | 1.00 | 0.85 | 110 | 1.00 | 17.11 | 0.857 | 0.80 | **11.74** |
| 4 | 9.67 | 33.34 | 0.72 | 1.00 | 0.85 | 110 | 1.00 | 18.96 | 0.857 | 0.80 | **13.00** |
| 5 | 9.67 | 43.01 | 0.78 | 1.00 | 0.85 | 110 | 1.00 | 20.54 | 0.857 | 0.80 | **14.08** |
| 6 | 9.67 | 52.68 | 0.82 | 1.00 | 0.85 | 110 | 1.00 | 21.59 | 0.857 | 0.80 | **14.80** |
| 7 | 9.67 | 62.35 | 0.86 | 1.00 | 0.85 | 110 | 1.00 | 22.64 | 0.857 | 0.80 | **15.53** |
| 8 | 9.67 | 72.02 | 0.90 | 1.00 | 0.85 | 110 | 1.00 | 23.70 | 0.857 | 0.80 | **16.25** |
| 9 | 9.67 | 81.69 | 0.94 | 1.00 | 0.85 | 110 | 1.00 | 24.75 | 0.857 | 0.80 | **16.97** |

***North/South Wind Load Calc. (Windward Face)***

| story | story height | height (ft) | $k_z$ | $k_{zt}$ | $k_d$ | V | I | $q_h$ | $G_f$ | $C_p$ | $p_z$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 14.00 | 14.00 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 3 | 9.67 | 23.67 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 4 | 9.67 | 33.34 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 5 | 9.67 | 43.01 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 6 | 9.67 | 52.68 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 7 | 9.67 | 62.35 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 8 | 9.67 | 72.02 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |
| 9 | 9.67 | 81.69 | 1.13 | 1.00 | 0.85 | 110 | 1.00 | 29.75 | 0.857 | -0.30 | **-7.65** |

**North/ South Wind Load Diagram of 8 story tower**



**Seismic Loads:**

Seismic loads were calculated using ASCE 7-05 Chapter 11 and 12; specifically the Equivalent Lateral Force Procedure of Chapter 12 was used directly. It was determined that the base shear described by this method matched the base shear used in the actual design to 5%.

**15 story tower dead load:**

| Floor | Story ht. (ft) | Elev. (ft) | $h_i$ (ft) | SLAB AREA ($ft^2$) | SLAB OPN'G ($ft^2$) | NET SLAB AREA ($ft^2$) | SLAB DL [psf] | SDL [psf] | Slab weight [kips] | Misc LL [psf] |
|---|---|---|---|---|---|---|---|---|---|---|
| Bulkhead | | 197.08 | 160.25 | 535 | 0 | 535 | 150 | 0 | 80 | 0 |
| | 9.00 | | | | | | | | | |
| Roof | | 188.08 | 151.25 | 4410 | 200 | 4210 | 150 | 10 | 674 | 0 |
| | 10.66 | | | | | | | | | |
| 15 | | 177.42 | 140.59 | 6900 | 200 | 6700 | 175 | 15 | 1273 | 0 |
| | 10.67 | | | | | | | | | |
| 14 | | 166.75 | 129.92 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 13 | | 157.08 | 120.25 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.66 | | | | | | | | | |
| 12 | | 147.42 | 110.59 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 11 | | 137.75 | 100.92 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 10 | | 128.08 | 91.25 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.66 | | | | | | | | | |
| 9 | | 118.42 | 81.59 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 8 | | 108.75 | 71.92 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 7 | | 99.08 | 62.25 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.66 | | | | | | | | | |
| 6 | | 89.42 | 52.59 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 5 | | 79.75 | 42.92 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |
| 4 | | 70.08 | 33.25 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.66 | | | | | | | | | |
| 3 | | 60.42 | 23.59 | 6900 | 200 | 6700 | 100 | 15 | 771 | 0 |
| | 9.67 | | | | | | | | | |

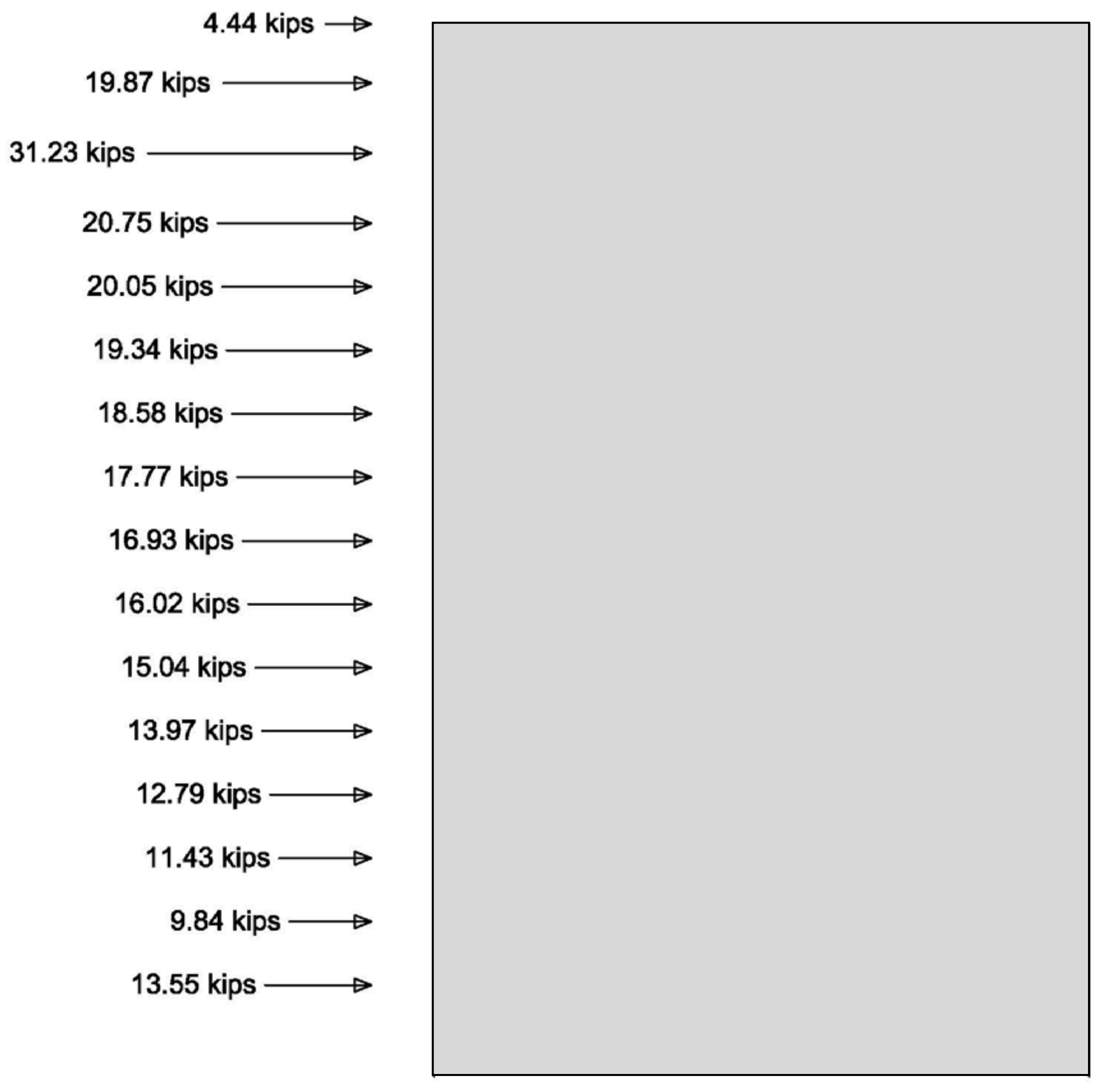
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 50.75 | 13.92 | 9850 | 200 | 9650 | 116 | 15 | 1261 | 0 |
| | 13.92 | | | | | | | | | |
| Base | | 36.83 | 0.00 | | | | | | | |

| Floor | Brick & Block Façade [ft.] | Window/ Stone Façade [ft] | Façade DL [kips] | Cols [$ft^2$] | Shear walls [$ft^2$] | Cols [kips] | Shear walls [kips] | Beams [kips] | Eqmt [kips] | W (floor) [kips] |
|---|---|---|---|---|---|---|---|---|---|---|
| Bulkhead | | | | | | | | 0 | 0 | 235 |
| | 100 | 0 | 90 | 3 | 45 | 4 | 61 | | | |
| Roof | | | | | | | | 0 | 50 | 1,079 |
| | 90 | 200 | 181 | 32 | 77 | 51 | 123 | | | |
| 15 | | | | | | | | 5 | 0 | 1,751 |
| | 140 | 200 | 235 | 56 | 93 | 90 | 149 | | | |
| 14 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 13 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 12 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 11 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 10 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 9 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 8 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 7 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 6 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 5 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 4 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 3 | | | | | | | | 5 | 0 | 1,204 |
| | 140 | 200 | 213 | 56 | 93 | 81 | 135 | | | |
| 2 | | | | | | | | 5 | 0 | 2,088 |
| | 275 | 100 | 438 | 79 | 105 | 165 | 219 | | | |
| Base | | | | | | | | | | |
| | | | | | | | | **Total Weight** | | **19,604** |

| $C_s$ | W [kips] | V [kips] |
|---|---|---|
| 0.013344 | 19,604 | 262 |

| Floor | k | $h_x$ | $w_x$ | $w_x h_x^k$ | $\Sigma w_i h_i^k$ | $C_v$ | $F_x$ [kips] |
|---|---|---|---|---|---|---|---|
| Bulkhead | 0.437 | 160.250 | 235.050 | 2162.769 | | 0.017 | 4.438 |
| Roof | 0.437 | 151.250 | 1079.111 | 9681.486 | | 0.076 | 19.868 |
| 15 | 0.437 | 140.590 | 1751.215 | 15217.362 | | 0.119 | 31.229 |
| 14 | 0.437 | 129.920 | 1204.365 | 10110.504 | | 0.079 | 20.748 |
| 13 | 0.437 | 120.250 | 1203.921 | 9770.758 | | 0.077 | 20.051 |
| 12 | 0.437 | 110.590 | 1204.365 | 9422.996 | | 0.074 | 19.338 |
| 11 | 0.437 | 100.920 | 1204.365 | 9053.508 | | 0.071 | 18.579 |
| 10 | 0.437 | 91.250 | 1203.921 | 8660.314 | | 0.068 | 17.772 |
| 9 | 0.437 | 81.590 | 1204.365 | 8249.913 | | 0.065 | 16.930 |
| 8 | 0.437 | 71.920 | 1204.365 | 7807.259 | | 0.061 | 16.022 |
| 7 | 0.437 | 62.250 | 1203.921 | 7326.966 | | 0.057 | 15.036 |
| 6 | 0.437 | 52.590 | 1204.365 | 6808.763 | | 0.053 | 13.973 |
| 5 | 0.437 | 42.920 | 1204.365 | 6230.052 | | 0.049 | 12.785 |
| 4 | 0.437 | 33.250 | 1203.921 | 5570.121 | | 0.044 | 11.431 |
| 3 | 0.437 | 23.590 | 1204.365 | 4795.787 | | 0.038 | 9.842 |
| 2 | 0.437 | 13.920 | 2088.203 | 6602.771 | 127471.328 | 0.052 | 13.550 |

**Seismic Load Diagram for 15 story tower**



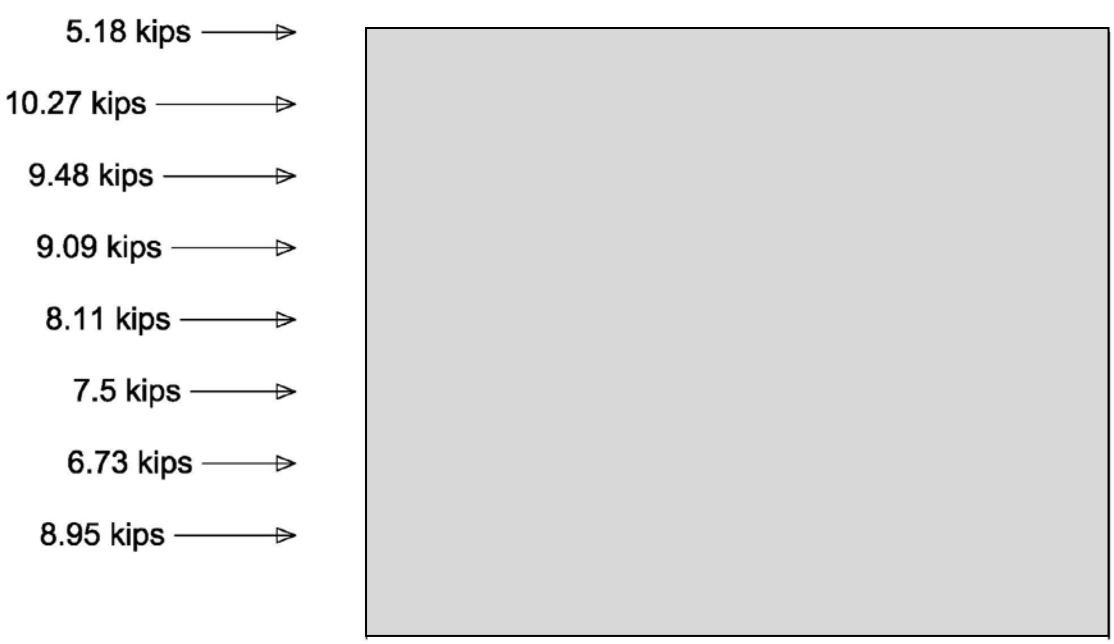
**8 Story Tower Dead Load:**

| Floor | Story ht. (ft) | Elev. (ft) | $h_i$ (ft) | SLAB AREA ($ft^2$) | SLAB OPN'G ($ft^2$) | NET SLAB AREA ($ft^2$) | SLAB DL [psf] | SDL [psf] | Slab weight [kips] | Misc LL [psf] |
|---|---|---|---|---|---|---|---|---|---|---|
| Bulkhead | | 124.54 | 89.53 | 455 | 0 | 455 | 100 | 0 | 46 | 0 |
| | 9.00 | | | | | | | | | |
| Roof | | 115.54 | 80.53 | 1460 | 150 | 1310 | 100 | 0 | 131 | 0 |
| | 10.66 | | | | | | | | | |
| 8 | | 104.88 | 69.87 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.67 | | | | | | | | | |
| 7 | | 95.21 | 60.20 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.69 | | | | | | | | | |
| 6 | | 85.52 | 50.51 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.64 | | | | | | | | | |
| 5 | | 75.88 | 40.87 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.67 | | | | | | | | | |
| 4 | | 66.21 | 31.20 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.67 | | | | | | | | | |
| 3 | | 56.54 | 21.53 | 1460 | 150 | 1310 | 100 | 15 | 151 | 0 |
| | 9.66 | | | | | | | | | |
| 2 | | 46.88 | 11.87 | 2160 | 150 | 2010 | 116 | 15 | 264 | 0 |
| | 11.87 | | | | | | | | | |
| Base | | 35.01 | 0.00 | | | | | | | |

| Floor | Brick & Block Façade [ft.] | Window/Stone Façade [ft] | Façade DL [kips] | Cols [ft²] | Shear walls [ft²] | Cols [kips] | Shear walls [kips] | Beams [kips] | Eqmt [kips] | W (floor) [kips] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | psf for brick & block | | | | | | | |
| | | 40 | psf @ windows/precast | | | | | | | |
| Bulkhead | | | | | | | | 0 | 0 | 205 |
| | 95 | 0 | 86 | 0 | 55 | 0 | 74 | | | |
| Roof | | | | | | | | 5 | 10 | 420 |
| | 140 | 45 | 168 | 11 | 55 | 18 | 88 | | | |
| 8 | | | | | | | | 5 | 0 | 404 |
| | 140 | 45 | 153 | 11 | 55 | 16 | 80 | | | |
| 7 | | | | | | | | 5 | 0 | 405 |
| | 140 | 45 | 153 | 11 | 55 | 16 | 80 | | | |
| 6 | | | | | | | | 5 | 0 | 403 |
| | 140 | 45 | 152 | 11 | 55 | 16 | 80 | | | |
| 5 | | | | | | | | 5 | 0 | 404 |
| | 140 | 45 | 153 | 11 | 55 | 16 | 80 | | | |
| 4 | | | | | | | | 5 | 0 | 404 |
| | 140 | 45 | 153 | 11 | 55 | 16 | 80 | | | |
| 3 | | | | | | | | 5 | 0 | 404 |
| | 140 | 45 | 153 | 11 | 55 | 16 | 80 | | | |
| 2 | | | | | | | | 5 | 0 | 639 |
| | 200 | 25 | 249 | 13 | 55 | 23 | 98 | | | |
| Base | | | | | | | | | □ | |
| | | | | | | | | Total Weight | | 3,689 |

| $C_s$ | W [kips] | V [kips] |
|---|---|---|
| 0.020042 | 3,689 | 74 |

| k | $h_x$ | $w_x$ | $w_x h_x^k$ | $\Sigma w_i h_i^k$ | $C_v$ | $F_x$ [kips] |
|---|---|---|---|---|---|---|
| 0.291 | 89.530 | 205.250 | 759.303 | | 0.070 | 5.177 |
| 0.291 | 80.530 | 419.962 | 1506.435 | | 0.139 | 10.270 |
| 0.291 | 69.870 | 404.169 | 1391.088 | | 0.128 | 9.484 |
| 0.291 | 60.200 | 404.683 | 1333.758 | | 0.123 | 9.093 |
| 0.291 | 50.510 | 403.398 | 1263.315 | | 0.116 | 8.613 |
| 0.291 | 40.870 | 404.169 | 1190.068 | | 0.110 | 8.113 |
| 0.291 | 31.200 | 404.169 | 1100.134 | | 0.101 | 7.500 |
| 0.291 | 21.530 | 403.912 | 986.909 | | 0.091 | 6.728 |
| 0.291 | 11.870 | 639.157 | 1313.205 | 10844.216 | 0.121 | 8.953 |



# Appendix A – Calculations

WIND LOAD PER ASCE 7-05:

METHOD 2:

BASIC WIND SPEED (V) = 110 MPH (FIG 6-1C)

WIND DIRECTIONALITY FACTOR ($K_d$) = 0.85 (TABLE 6-4)

IMPORTANCE FACTOR (I) = 1.0 (TABLE 6-1)
{OCCUPANCY CAT. II PER IBC 2006}

EXPOSURE CAT B (6.5.6)

TOPOGRAPHIC FACTOR ($K_{zt}$) = 1.00 (6.5.7)

NATURAL FREQUENCY: ($n_1$) ((6-16)

$$n_1 = 385 (C_w)^{0.5}/H$$

$$C_w = \frac{100}{A_B} \sum_{i=1}^{n} \left(\frac{H}{h_i}\right)^2 \frac{A_i}{\left[1 + 0.83\left(\frac{h_i}{d_i}\right)^2\right]}$$

⇒ SEE SPREAD SHEET FOR $n_1$ & $C_w$

FIND $n_1 = 0.276 < 1.0$ ∴ FLEXIBLE

GUST EFFECT FACTOR: ($G_f$)

- $g_R = \sqrt{2 \ln[3600 n_1]} + \frac{0.577}{\sqrt{2\ln[3600 n_1]}}$

$$= \sqrt{2\ln[(3600)(0.276)]} + \frac{0.577}{2\ln[(3600)(0.276)]}$$

$g_R = 3.87$

- $\bar{z} = 0.6h = 0.6(154) = \underline{92.4}$

$\bar{z} > z_{min} = 30$ ✓

- $I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.3\left(\frac{33}{92.4}\right)^{1/6} = 0.253$

- $L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 320\left(\frac{92.4}{33}\right)^{1/3} = \underline{451}$

2

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} = \frac{1}{1+0.63\left(\frac{99+99}{451}\right)}$$

$$Q = 0.834$$

$$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V\left(\frac{88}{68}\right)$$

$$= 0.45\left(\frac{92.4}{33}\right)^{1/4}(110)\left(\frac{88}{68}\right) = 93.91$$

$$N_1 = \frac{n_1 L_z}{\bar{V}_z} = \frac{(0.276)(451)}{93.91} = 1.32$$

$$R_n = \frac{7.47 N_1}{(1+10.3N_1)^{5/3}} = \frac{(7.47)(1.32)}{(1+10(1.32))^{5/3}} = 0.113$$

$$n_h = 4.6 n_1 h/\bar{V}_z = (4.6)(0.276)(154)/93.91$$

$$= 3.99$$

$$R_h = \frac{1}{3.99} - \frac{1}{2(3.99)^2}\left(1-e^{-2(3.99)}\right) = 0.22$$

SEE SPREADSHEET TO FIND THAT

$R_B = 0.487$

$R_L = 0.198$

- $\beta = 0.02$ (C6.5.8)
- $R = \sqrt{\left(\frac{1}{0.02}\right)(0.113)(0.22)(0.487)(0.53+(0.47)(0.198))}$

$$= 0.792$$

$$G_f = 0.925\left(\frac{1+(1.7)(0.025)\sqrt{(3.4^2)(0.834^2)+(3.87^2)(0.792^2)}}{1+1.7(3.4)(0.253)}\right)$$

$$\boxed{G_F = 1.05}$$

3

Cp (WINDWARD WALL) $C_p = 0.8$ (FIG 6-6)

Cp (LEEWARD WALL) $C_p = -0.3$ (FIG 6-6)

DESIGN PRESSURE AT TOP OF BUILDING:

$$q_p = 0.00256 K_z K_{zt} K_d V^2 I$$

$$= (0.00256)(1.13)(1.0)(0.85)(110)^2(1.0)$$

$$= 29.75 \text{ PSF}$$

$$P_p = q_p G_f C_p = (29.75)(1.05)(0.8)$$

$$P_p = 23.1 \text{ PSF}$$

SEE SPREAD SHEETS FOR REST OF LOADS.

Natural Frequency Calc. (North/South Direction) 8 story tower Per ASCE 7-05 C6-16

| Shear Wall | H (ft) | $A_B$ (sq. ft) | $h_i$ (ft) | $A_i$ (sq. ft) | $D_i$ (ft) | $c_{w,n}$ |
|---|---|---|---|---|---|---|
| 33 | 82 | 2280 | 82 | 15.7 | 15.7 | 0.029127 |
| 34 | 82 | 2280 | 82 | 23 | 23 | 0.08734 |

$c_w =$ 0.116467

$n_1 =$ 1.602313 RIGID

Gust Factor Calculation Per ASCE 7-05 6.5.8.2 (8 story tower)
RIGID BUILDING

| | | ASCE 7-05 Code Reference |
|---|---|---|
| h (ft) | 82 | |
| L (ft) | 99 | |
| B (ft) | 23 | |
| V | 110 | |
| $g_Q$ | 3.4 | 6.5.8.2 |
| $g_v$ | 3.4 | 6.5.8.2 |
| $n_1$ | 1.602313 | C6.5.8 EQ.(C6-16) |
| z | 49.2 | Table 6-2 |
| c | 0.3 | Table 6-2 |
| $I_z$ | 0.280681 | 6.5.8.1 EQ. (6-5) |
| $\ell$ | 320 | Table 6-2 |
| $\epsilon$ | 0.333333 | Table 6-2 |
| $L_z$ | 365.567 | 6.5.8.1 EQ. (6-7) |
| Q | 0.881445 | 6.5.8.1 EQ. (6-6) |
| G | 0.857156 | 6.5.8.2 EQ.(6-8) |

Natural Frequency Calc. (North/South Direction) Per ASCE 7-05 C6-16 (15 story tower)

| Shear Wall | H (ft) | $A_B$ (sq. ft) | $h_i$ (ft) | $A_i$ (sq. ft) | $D_i$ (ft) | $c_{w,n}$ |
|---|---|---|---|---|---|---|
| 13 | 154 | 9800 | 154 | 26.25 | 21 | 0.005869 |
| 16A | 154 | 9800 | 174 | 8.75 | 8.75 | 0.000212 |
| 16B | 154 | 9800 | 174 | 8.75 | 8.75 | 0.000212 |
| 20 | 154 | 9800 | 154 | 26.5 | 21 | 0.005925 |

$c_w$ = 0.01222

$n_1$ = 0.276357

Gust Factor Calculation Per ASCE 7-05 6.5.8.2 (15 story tower)

| | | |
|---|---|---|
| h (ft) | 154 | ASCE 7-05 Code Reference |
| L (ft) | 99 | |
| B (ft) | 99 | |
| V | 110 | |
| $g_Q$ | 3.4 | 6.5.8.2 |
| $g_v$ | 3.4 | 6.5.8.2 |
| $n_1$ | 0.276357 | C6.5.8 EQ.(C6-16) |
| $g_R$ | 3.870836 | 6.5.8.2 EQ.(6-9) |
| z | 92.4 | Table 6-2 |
| c | 0.3 | Table 6-2 |
| $I_z$ | 0.252694 | 6.5.8.1 EQ. (6-5) |
| $\ell$ | 320 | Table 6-2 |
| ∈ | 0.333333 | Table 6-2 |
| $L_z$ | 451.0271 | 6.5.8.1 EQ. (6-7) |
| Q | 0.834005 | 6.5.8.1 EQ. (6-6) |
| *b* | 0.45 | Table 6-2 |
| α | 0.25 | Table 6-2 |
| $V_z$ | 93.91309 | 6.5.8.2 EQ.(6-14) |
| $N_1$ | 1.327235 | 6.5.8.2 EQ.(6-12) |
| $R_n$ | 0.11277 | 6.5.8.2 EQ.(6-11) |
| $\eta_h$ | 2.084604 | 6.5.8.2 EQ.(6-13) |
| $R_h$ | 0.366427 | 6.5.8.2 EQ.(6-13) |
| $\eta_B$ | 1.340103 | 6.5.8.2 EQ.(6-13) |
| $R_B$ | 0.486881 | 6.5.8.2 EQ.(6-13) |
| $\eta_L$ | 4.486431 | 6.5.8.2 EQ.(6-13) |
| $R_L$ | 0.198057 | 6.5.8.2 EQ.(6-13) |
| β | 0.02 | C6.5.8 |
| R | 0.7917 | 6.5.8.2 EQ.(6-10) |
| $G_f$ | 1.050185 | 6.5.8.2 EQ.(6-8) |

Natural Frequency Calc. (East/West Direction) Per ASCE 7-05 C6-16 (8 story tower)

| Shear Wall | H (ft) | $A_B$ (sq. ft) | $h_i$ (ft) | $A_i$ (sq. ft) | $D_i$ (ft) | $c_{w,n}$ |
|---|---|---|---|---|---|---|
| 33 | 82 | 2280 | 82 | 7.83 | 7.83 | 0.003732 |
| 34 | 82 | 2280 | 82 | 8 | 8 | 0.003978 |

$c_w$ = 0.00771

$n_1$ = 0.412256 FLEXIBLE

Gust Factor Calculation (East/West Direction) Per ASCE 7-05 6.5.8.2 (8 story tower)
FLEXIBLE STRUCTURE

| | | ASCE 7-05 Code Reference |
|---|---|---|
| h (ft) | 82 | |
| L (ft) | 23 | |
| B (ft) | 99 | |
| V | 110 | |
| $g_Q$ | 3.4 | 6.5.8.2 |
| $g_v$ | 3.4 | 6.5.8.2 |
| $n_1$ | 0.412256 | C6.5.8 EQ.(C6-16) |
| $g_R$ | 3.972651 | 6.5.8.2 EQ.(6-9) |
| z | 49.2 | Table 6-2 |
| c | 0.3 | Table 6-2 |
| $I_z$ | 0.280681 | 6.5.8.1 EQ. (6-5) |
| $\ell$ | 320 | Table 6-2 |
| $\epsilon$ | 0.333333 | Table 6-2 |
| $L_z$ | 365.567 | 6.5.8.1 EQ. (6-7) |
| Q | 0.843774 | 6.5.8.1 EQ. (6-6) |
| *b* | 0.45 | Table 6-2 |
| α | 0.25 | Table 6-2 |

| | | |
|---|---|---|
| $V_z$ | 80.22309 | 6.5.8.2 EQ.(6-14) |
| $N_1$ | 1.878602 | 6.5.8.2 EQ.(6-12) |
| $R_n$ | 0.092519 | 6.5.8.2 EQ.(6-11) |
| $\eta_h$ | 1.938382 | 6.5.8.2 EQ.(6-13) |
| $R_h$ | 0.385578 | 6.5.8.2 EQ.(6-13) |
| $\eta_B$ | 2.340242 | 6.5.8.2 EQ.(6-13) |
| $R_B$ | 0.336858 | 6.5.8.2 EQ.(6-13) |
| $\eta_L$ | 1.820188 | 6.5.8.2 EQ.(6-13) |
| $R_L$ | 0.402437 | 6.5.8.2 EQ.(6-13) |
| $\beta$ | 0.02 | C6.5.8 |
| R | 0.657335 | 6.5.8.2 EQ.(6-10) |
| $G_f$ | 1.005682 | 6.5.8.2 EQ.(6-8) |

Natural Frequency Calc. (East/West Direction) Per ASCE 7-05 C6-16 (15 story tower)

| Shear Wall | H (ft) | $A_B$ (sq. ft) | $h_i$ (ft) | $A_i$ (sq. ft) | $D_i$ (ft) | $c_{w,n}$ |
|---|---|---|---|---|---|---|
| 13 | 154 | 9800 | 154 | 9.3 | 9.3 | 0.000415 |
| 16 | 154 | 9800 | 174 | 26 | 26 | 0.005444 |
| 20 | 154 | 9800 | 154 | 8.7 | 8.7 | 0.00034 |

$c_w =$ 0.006199

$n_1 =$ 0.19684 FLEXIBLE

Gust Factor Calculation (East/West Direction) Per ASCE 7-05 6.5.8.2 (15 story tower)

FLEXIBLE STRUCTURE

| | | ASCE 7-05 Code Reference |
|---|---|---|
| h (ft) | 154 | |
| L (ft) | 99 | |
| B (ft) | 99 | |
| V | 110 | |
| $g_Q$ | 3.4 | 6.5.8.2 |
| $g_v$ | 3.4 | 6.5.8.2 |
| $n_1$ | 0.19684 | C6.5.8 EQ.(C6-16) |
| $g_R$ | 3.782329 | 6.5.8.2 EQ.(6-9) |
| z | 92.4 | Table 6-2 |
| c | 0.3 | Table 6-2 |
| $I_z$ | 0.252694 | 6.5.8.1 EQ. (6-5) |
| $\ell$ | 320 | Table 6-2 |
| Є | 0.333333 | Table 6-2 |
| $L_z$ | 451.0271 | 6.5.8.1 EQ. (6-7) |
| Q | 0.834005 | 6.5.8.1 EQ. (6-6) |
| *b* | 0.45 | Table 6-2 |
| α | 0.25 | Table 6-2 |
| $V_z$ | 93.91309 | 6.5.8.2 EQ.(6-14) |
| $N_1$ | 0.945345 | 6.5.8.2 EQ.(6-12) |
| $R_n$ | 0.135135 | 6.5.8.2 EQ.(6-11) |
| $\eta_h$ | 1.484794 | 6.5.8.2 EQ.(6-13) |
| $R_h$ | 0.458337 | 6.5.8.2 EQ.(6-13) |
| $\eta_B$ | 0.95451 | 6.5.8.2 EQ.(6-13) |
| $R_B$ | 0.58021 | 6.5.8.2 EQ.(6-13) |
| $\eta_L$ | 3.195534 | 6.5.8.2 EQ.(6-13) |
| $R_L$ | 0.264054 | 6.5.8.2 EQ.(6-13) |
| β | 0.02 | C6.5.8 |
| R | 1.084123 | 6.5.8.2 EQ.(6-10) |
| $G_f$ | 1.18104 | 6.5.8.2 EQ.(6-8) |

SEISMIC CALC PER ASCE 7-05:
(15 STORY TOWER)

$S_S = 0.362$
$S_1 = 0.070$ } 11.4.1 [EARTHQUAKE.USGS.GOV]

OCCUPANCY CAT. = II (IBC 2006 1604.5)

SOIL SITE CLASS B PER GEO. REPORT

$F_a = 1$
$F_v = 1$ } TABLE 11.4.1 & 2

$S_{MS} = F_a S_S = (1)(0.362) = 0.362$ (EQ. 11.4-1)

$S_{M1} = F_v S_1 = (1)(0.07) = 0.07$ (EQ. 11.4-2)

$S_{DS} = 2/3\, S_{MS} = 2/3(0.362) = 0.241$ (EQ. 11.4-3)

$S_{D1} = 2/3\, S_{M1} = 2/3(0.07) = 0.047$ (EQ. 11.4-4)

$T_a = C_t h_n^x$

$C_t = 0.02$ (TABLE 12.8-2)

$x = 0.75$ (TABLE 12.8-2)

$T_a = (0.02)(154)^{0.75} = 0.874$ SEC.

RESPONSE MODIFICATION COEFFICIENT (R) = 4 (TABLE 12.2-1)

↳ ORDINARY REINF. CONC. SHEAR WALLS

IMPORTANCE FACTOR (I) = 1.0 (TABLE 11.5-1)

$T_L = 6.0$ (FIG 22-15)

$C_s = S_{DS}/(R/I) = (0.241)/(4) = 0.06$

$C_{s\,MAX} = \frac{S_{D1}}{T(R/I)} = \frac{0.047}{(0.847)(4)} = 0.0133$ ⟵ GOVERNS.

↳ FOR $T \le T_L$

Determination of Cs for 15 story tower

| | | ASCE 7-05 CODE REFERENCE |
|---|---|---|
| Building Height (h) | 154 | |
| $S_s$ | 0.362 | 11.4.1 |
| $S_1$ | 0.07 | 11.4.1 |
| Occupancy Category | II | IBC 2006 1604.5 |
| Soil Site Class | B | 11.4.2 |
| $F_a$ | 1 | TABLE 11.4-1 |
| $F_v$ | 1 | TABLE 11.4-1 |
| $S_{MS}$ | 0.362 | EQ. 11.4-1 |
| $S_{M1}$ | 0.07 | EQ. 11.4-2 |
| $S_{DS}$ | 0.241333333 | EQ. 11.4-3 |
| $S_{D1}$ | 0.046666667 | EQ. 11.4-4 |
| $T_L$ | 6 | FIG. 22-15 |
| $C_t$ | 0.02 | TABLE 12.8-2 |
| x | 0.75 | TABLE 12.8-2 |
| $T_a$ | 0.874320248 | EQ. 12.8-7 |
| R | 4 | TABLE 12.2-1 |
| Importance Factor | 1 | TABLE 11.5-1 |
| $C_S$ | 0.060333333 | EQ. 12.8-2 |
| $C_{S,MAX}$ | 0.0133437 | EQ. 12.8-3 |
| | | |
| Use $C_S$ | 0.0133437 | 12.8.1.1 |

Determination of Cs for 8 story tower

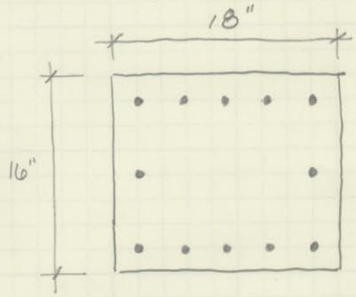
| | | ASCE 7-05 CODE REFERENCE |
|---|---|---|
| Building Height (h) | 89.53 | |
| $S_s$ | 0.362 | 11.4.1 |
| $S_1$ | 0.07 | 11.4.1 |
| Occupancy Category | II | IBC 2006 1604.5 |
| Soil Site Class | B | 11.4.2 |
| $F_a$ | 1 | TABLE 11.4-1 |
| $F_v$ | 1 | TABLE 11.4-1 |
| $S_{MS}$ | 0.362 | EQ. 11.4-1 |
| $S_{M1}$ | 0.07 | EQ. 11.4-2 |
| $S_{DS}$ | 0.241333333 | EQ. 11.4-3 |
| $S_{D1}$ | 0.046666667 | EQ. 11.4-4 |
| $T_L$ | 6 | FIG. 22-15 |
| $C_t$ | 0.02 | TABLE 12.8-2 |
| x | 0.75 | TABLE 12.8-2 |
| $T_a$ | 0.582111842 | EQ. 12.8-7 |
| R | 4 | TABLE 12.2-1 |
| Importance Factor | 1 | TABLE 11.5-1 |
| $C_S$ | 0.060333333 | EQ. 12.8-2 |
| $C_{S,MAX}$ | 0.020041968 | EQ. 12.8-3 |
| | | |
| Use $C_S$ | 0.020041968 | 12.8.1.1 |

COMPRESSION MEMBER CHECK PER ACI 318-05

COLUMN 25:

SIZE = 18×16

REINF. = 12 #8 LONG., #3@12" OC TIES.




$\phi P_n = (0.80)\phi[0.85 f'_c (A_g - A_{st}) + f_y A_{st}]$ ......... 10.3.6.2

$= (0.80)(0.65)[0.85(5)((16 \times 18) - (12 \times 0.79)) + 60(12)(0.79)]$

$= 911$ KIPS

COL 25 TRIB AREA PER FLOOR:

GROUND FLOOR:

$A_{TRIB} = \left(\frac{64'\text{-}7" - 27'\text{-}3"}{2}\right)\left(\frac{87'\text{-}10" - 51'\text{-}9"}{2}\right)$

$= 336.7\ FT^2$

DEAD LOAD

CONC. = (10/12 FT)(150 PCF) = 125 PSF

MEP/PARTITIONS = 15 PSF

LIVE LOAD

RETAIL/LOBBY SPACE = 100 PSF

2

GROUND FLOOR LOAD

$P_D = (140\ PSF)(336.7\ FT^2) = 47.14^K$

$P_L = (100\ PSF)(336.7\ FT^2) = 33.67^K$

SECOND FLOOR THROUGH 14th FLOOR:

$$A_{TRIB} = \left(\frac{64'\text{-}7'' - 27'\text{-}3''}{2}\right)\left(\frac{67'\text{-}3\tfrac{3}{4}'' - 51'\text{-}9''}{2}\right)$$

$= 145.25\ FT^2$

DEAD LOAD

CONC. = (8/12 FT)(150 PCF) = 100 PSF

MEP/PARTITIONS = 15 PSF

LIVE LOAD

RESIDENTIAL = 40 PSF

SECOND THROUGH 14th FLOOR LOAD:

$P_D = (115\ PSF)(145.25\ FT^2)(13\ FLOORS) = 217.15^K$

$P_L = (40\ PSF)(145.25\ FT^2)(13\ FLOORS) = 75.53^K$

15th FLOOR:

$A_{TRIB} = 145.25\ FT^2$

DEAD LOAD

CONC = (14/12)(150) = 175 PSF

MEP/PARTITIONS = 15 PSF

LIVE LOAD

RESIDENTIAL = 40 PSF

3

15th FLOOR LOAD

$P_D = (190\ PSF)(145.25\ FT^2) = 27.6^K$

$P_L = (40\ PSF)(145.25\ FT^2) = 5.81^K$

TOTAL LOAD:

$P_D = 27.6^K + 217.5^K + 47.14^K = 292.24^K$

$P_L = 5.81^K + 75.53^K + 33.67^K = 115.01^K$

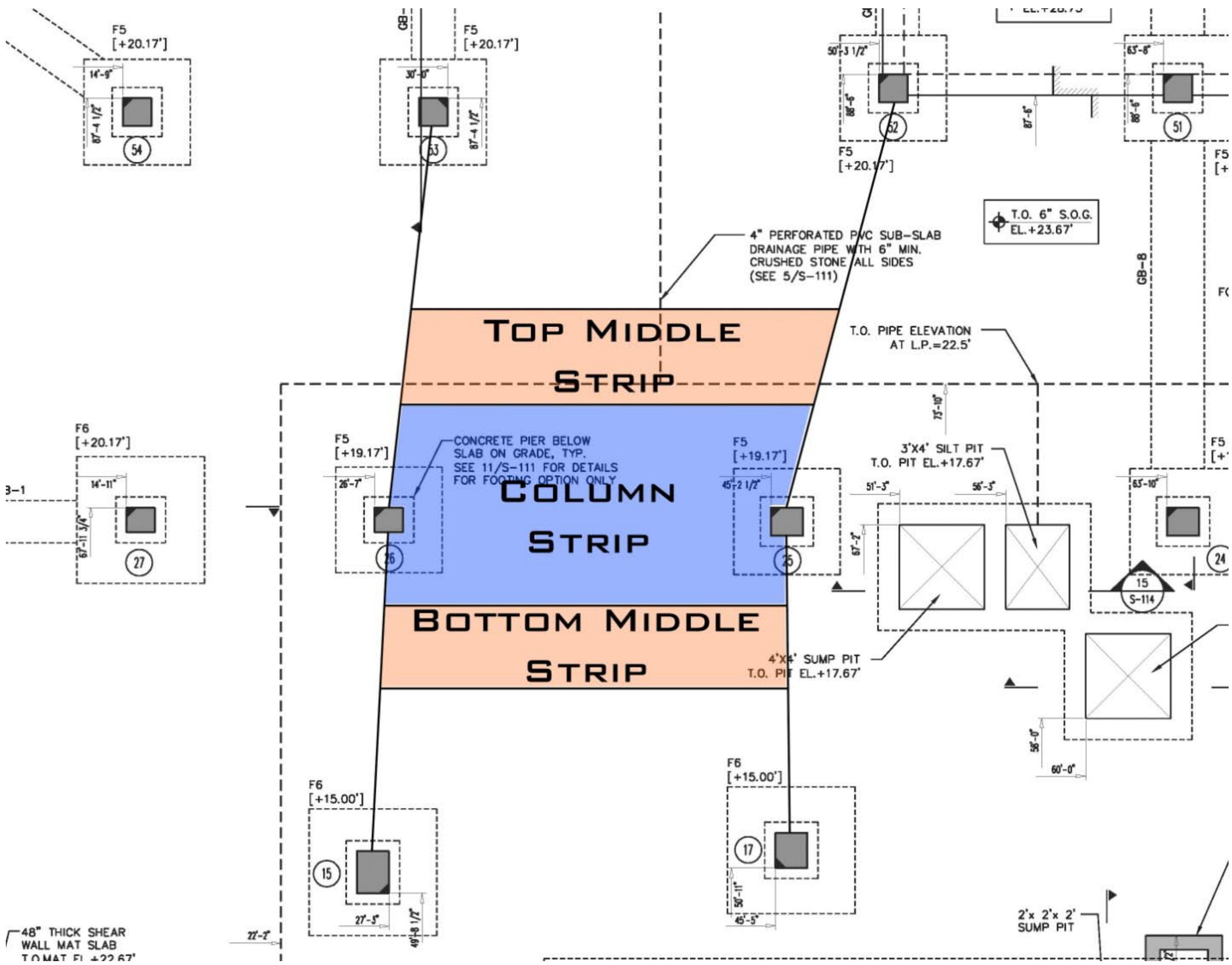
$P_U = 1.2D + 1.6L$

$= (1.2)(292.24) + (1.6)(115.01)$

$P_U = 534.7^K$

$\Rightarrow$ $\phi P_n > P_U$ $\therefore$ OK

Bay Used for Direct Design Method (ACI 318-05 Chapter 13.)



1/9

DIRECT DESIGN METHOD PER ACI 318-05 13.6

13.6.1 → LIMITATIONS

- MIN OF 3 CNTS. SPANS IN EACH DIRECTION ✓
- REGULAR PANELS WITH $\ell_1/\ell_2 \leq 2$ ✓
- SUCCESSIVE SPANS DO NOT DIFFER BY MORE THAN 1/3 THE LONGER SPAN ✓
- OFFSET OF COLUMNS BY A MAX OF 10% ✓
- GRAVITY ONLY AN L ≤ 2D ✓

COL 15

CENTER @ (26'-6", 50'-8½")

COL 17

CENTER @ (46'-2", 51'-9")

COL 26

CENTER @ (27'-3", 68'-6¾")

SIZE = 16" x 14"

COL 25

CENTER @ (45'-11½", 68'-7¾")

SIZE = 18" x 16"

COL 53

CENTER @ (30'-8", 86'-8½")

COL 52

CENTER @ (50'-11½", 87'-10")

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$\ell_1 = (45'\text{-}11\tfrac{1}{2}") - (27'\text{-}3")$

$= 18'\text{-}8\tfrac{1}{2}"$

$\ell_n = (18'\text{-}8\tfrac{1}{2}") - \tfrac{1}{2}(18") - \tfrac{1}{2}(16")$

$= 17'\text{-}3\tfrac{1}{2}"$

$\ell_2 = \dfrac{(87'\text{-}10") - (50'\text{-}8\tfrac{1}{2}")}{2}$

$= 19'\text{-}3\tfrac{1}{4}"$

DEAD LOADS:

CONC. $= (150 \text{ PCF})(10/12 \text{ FT}) = 125$ PSF

MEP/PARTITIONS $= 15$ PSF

LIVE LOADS:

RETAIL/LOBBY $= 100$ PSF

$q_u = 1.2D + 1.6L$

$= 1.2(140) + 1.6(100)$

$= 328$ PSF

$M_o = \dfrac{q_u \ell_2 \ell_n^2}{8}$ .................... 13.6.2.2

$= \dfrac{(0.328)(19.27)(17.29)^2}{8}$

$= 237$ ft-K

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NEGATIVE FACTORED MOMENT
& POSITIVE FACTORED MOMENT . . . . . . . ACI 318-05 13.6.3.2

$M^- = (0.65)(237\ ft\text{-}k)$
$= 154\ ft\text{-}k$

$M^+ = (0.35)(237\ ft\text{-}k)$
$= 83\ ft\text{-}k$

COLUMN STRIP MOMENTS . . . . . . . . ACI 318-05 13.6.4.1

$\frac{\ell_1}{\ell_2} = \frac{18'\text{-}8\frac{1}{2}''}{19'\text{-}3\frac{1}{4}''} = 0.97$

$M^-_{COL\ STRIP} = (0.75)(154)$
$= 116\ ft\text{-}k$

$M^+_{COL\ STRIP} = (0.6)(83)$
$= 50\ ft\text{-}k$

MIDDLE STRIP MOMENTS . . . . . . . . . . ACI 318-05 13.6.6.1

$M^-_{MID\ STRIP} = (0.25)(154)$
$= 39\ ft\text{-}k$

$M^+_{MID\ STRIP} = (0.4)(83)$
$= 34\ ft\text{-}k$

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SLAB STRENGTH: ($f'_c = 5$ ksi, $f_y = 60$ ksi)

COLUMN STRIP:

$b = 115.6"$

$h = 10"$

$d = 10 - \underset{CVR}{0.75} - \underset{2\text{-}\#5\ BARS}{2(0.625)}$

NEGATIVE MOMENT REINF.

10-#5 AND 12-#6

$A_s = 10(0.31) + 12(0.44)$

$= 8.38\ in^2$

$a = \dfrac{A_s f_y}{0.85 f'_c b} = \dfrac{(8.38)(60)}{(0.85)(5)(115.6)} = 1.02\ in$

$c = \dfrac{1.02}{\beta_1} = \dfrac{1.02}{0.8} = 1.28\ in$

$\dfrac{\varepsilon_y}{d-c} = \dfrac{\varepsilon_c}{c}$

$\Rightarrow \varepsilon_y = \dfrac{0.003}{1.28}(8 - 1.28) = 0.0158$

$\varepsilon_y > 0.005 \Rightarrow$ TENSION CONTROLLED AND $\phi = 0.9$

$\phi M_n = \phi A_s f_y (d - a/2)$

$= (0.9)(8.38)(60)(8 - \frac{1.02}{2})$

$= 3389$ in-k

$\phi M_n = 282$ ft-k

$\Rightarrow$ $\boxed{\phi M_n > M^-_{COL\ STRIP}\ \therefore\ \text{ok}}$

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POSITIVE MOMENT REINF.

#5 @ 12"

$\frac{115.6}{12} = 10$ BARS

$A_s = 10(0.31) = 3.1 \text{ in}^2$

$a = \frac{(3.1)(60)}{(0.85)(5)(115.6)} = 0.38$

$c = \frac{0.38}{0.8} = 0.48$

$\varepsilon_y = \frac{0.003}{0.48}(8 - 0.48)$

$= 0.047$

$\varepsilon_y > 0.005 \Rightarrow$ TENSION CONTROLLED AND $\phi = 0.9$

$\phi M_n = (3.1)(60)(8 - \frac{0.38}{2})$

$= 1452$ in-k

$\phi M_n = 121$ ft-k

$\Rightarrow$ $\phi M_n > M^+_{\text{COL STRIP}}$ $\therefore$ OK

MIDDLE STRIP:

$b = 115.6"$
$h = 10"$
$d = 8"$
$f'_c = 5$ ksi
$f_y = 60$ ksi

NEGATIVE MOMENT REINF.

#5 @ 12

$A_s = 9$ BARS

$A_s = 9(0.31) = 2.79 \text{ in}^2$

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$$a = \frac{(2.79)(60)}{(0.85)(5)(115.6)} = 0.34 \text{ in}$$

$$c = \frac{0.34}{0.8} = 0.43$$

$$\varepsilon_y = \frac{0.003}{0.43}(8 - 0.43) = 0.0528$$

$\varepsilon_y > 0.005 \Rightarrow$ TENSION CONTROLLED AND $\phi = 0.9$

$$\phi M_n = 0.9(2.79)(60)\left(8 - \frac{0.34}{2}\right)$$

$$= 1179 \text{ in-k}$$

$$\phi M_n = 98 \text{ ft-k}$$

$\Rightarrow$ $\phi M_n > M^-_{MID\ STRIP}$ $\therefore$ OK

POSITIVE MOMENT REINF.

SAME AS NEGATIVE MOMENT REINF.

$\Rightarrow \phi M_n = 98$ ft-k

$\phi M_n > M^+_{MID\ STRIP}$ $\therefore$ OK

STRENGTH OF COLUMN STRIP AND MIDDLE STRIP SELECTED EXCEEDS REQUIRED STRENGTH PER ACI 318-05 CHAPTER 13.

SLAB IS OK IN FLEXURE

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SLAB DEFLECTION:

LONGEST SPAN IS BTWN COL 11 & COL

$\ell_n = 24'-9\frac{1}{2}''$

MIN SLAB THICKNESS PER ACI 318-05 13.1.4

$t > 5\text{ in} \Rightarrow$ OK . . . . . . . . . . . . . . . 9.5.3.2

$t > \frac{\ell_n}{36}$ . . . . . . . . . . . . . . . . . . TABLE 9.5(c)

$t > \frac{297.5}{36} = 8.26\text{ in} \Rightarrow$ OK

SLAB THICKNESS EXCEEDS THAT REQUIRED BY 9.5.3 ∴ DEFLECTIONS NEED NOT BE CALCULATED.

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SHEAR PER ACI 318-05 CHAPTER 13

↳ PROVISIONS OF CHAPTER 11 SHALL APPLY

TWO WAY ACTION (PUNCHING SHEAR):

<u>COL 25</u>

18" x 16"

d = 8"

$\Rightarrow b_o = (16 + 8/2)2 + (18 + 8/2)2$ ...... ACI 318-05 11.12.1.2

$= 84"$

$V_c = \min \begin{cases} \cdot \left(2 + \frac{4}{\beta}\right)\sqrt{f'_c}\, b_o d & \text{.......... 11.12.2.1} \\ \cdot \left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f'_c}\, b_o d \\ \cdot\ 4\sqrt{f'_c}\, b_o d \end{cases}$

$\beta = \frac{18}{16} = 1.125$

$\alpha_s = 40$ FOR INT. COLUMNS

$\left(2 + \frac{4}{\beta}\right)\sqrt{f'_c}\, b_o d = \left(2 + \frac{4}{1.125}\right)\sqrt{5000}(84)(8)$

$= 263,986^{lbs} = 263.98^{KIPS}$

$\left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f'_c}\, b_o d = \left(\frac{(40)(8)}{84} + 2\right)\sqrt{5000}(84)(8)$

$= 276,054^{lbs} = 276.05^{KIPS}$

$4\sqrt{f'_c}\, b_o d = 4\sqrt{5000}(84)(8)$

$= 190,070^{lbs} = 190.07^{KIPS}$ ← GOVERNS

$V_c = 190.07^{KIPS}$

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TRIB AREA FOR COL 25

$$A_{TRIB} = \left(\frac{18'-7\frac{1}{2}''}{2} + \frac{18'-8\frac{1}{2}''}{2}\right)\left(\frac{20'-0''}{2} + \frac{15'-6''}{2}\right) - \left(\frac{22 \times 20}{144}\right)$$

$A_{TRIB} = 328.3\ FT^2$

$q_u = 328\ PSF$

$V_u = (328.3)(328)$
$= 107{,}683\ lbs$
$= 107.69\ KIPS$

$\phi V_c = (0.75)(190.07) = 142.55\ KIPS$

⇒ $\phi V_c > V_u \therefore$ ok

BEAM ACTION SHEAR PER ACI 318-05 CHAPT 11:

$b_w = 115.6'' \times 2 = 231\ in$

$V_c = 2\sqrt{f'_c}\, b_w d$ . . . . . . . . . . . . . . 11.3.1.1
$= 2\sqrt{5000}(231)(8)$
$= 261{,}346\ lbs = 261.34\ KIPS$

$\phi V_c = (0.75)(261.34)$
$= 196\ KIPS$

⇒ $\phi V_c > V_u \therefore$ ok