Letter of Transmittal

Date: September 25, 2015

To: Dr. Aly Said
The Pennsylvania State University
209 Engineering Unit A
University Park, PA 16802
aly.said@engr.psu.edu

From: Mark Bland
mab6037@psu.edu

Dear Dr. Said,

The enclosed documents include my Structural Notebook Submission A for AE481W – Senior Thesis. This report is a detailed structural analysis of West Village Housing's new North Building located on Towson University's campus.

This report includes a detailed structural analysis of the building codes, specifications and loads used on my thesis project. Included is a list of codes and documents used to compile this report. The analysis includes roof loads, snow loads and drifts, floor loads, exterior wall loads, wind pressures, and seismic forces.

Thank you for taking the time to read and review my report.

Sincerely,

Mark Bland

Building Codes, Specifications and Loads

Structural Notebook Submission A

West Village Housing Phases III & IV

Towson, Maryland

Mark Bland [Structural Option]

Advisor: Dr. Aly Said

September 25, 2015

Executive Summary

West Village Housing Phases III & IV is located on Emerson Drive in Towson Maryland on Towson University's campus. The project consists of two residential halls which will contain approximately 325,000 gross square feet of apartment-style accommodations for upper level students. The 9 and 11 story residence halls will contain a mix of two and four bedroom apartments. Each with single occupancy rooms and shared bathrooms, kitchens and living areas. Green roofs, penthouses and a basement are also planned to be included. The two buildings have not been named yet.

Structurally, the buildings are composed of 8" thick two-way post-tensioned concrete flat plates supported by concrete columns. Bays are roughly 27' by 20' with slight variances as the buildings shape changes. They are reinforced with ½" diameter un-bonded tendons in each direction and mild reinforcing, as required. In addition to the floor composition, perimeter steel angles will be provided at each floor level to support the exterior brick veneer with metal frame back up. 12" thick concrete shear walls will effectively resist the forces imposed on the building from all lateral loads. It shall be assumed that all stair and elevator walls be concrete shear walls.

The buildings began construction simultaneously in September of 2014 to address the continued demand for on-campus housing and are planned to be finished in the summer of 2016. They were designed considering live loads, gravity loads, snow loads, wind loads, seismic loads, and lateral loads. The lateral force resisting system in the building is primarily made up of shear walls that are located around the two stair towers of the structure. The project uses the 2012 Edition of the International Building Code and ASCE 7-10. Design loads were determined based on these codes, additional Baltimore Maryland County Codes and Ordinances, as well as practical engineering judgments.

For purposes of clarity and organization, this report and those following will be based off of the design and construction of the North building shown in Figure 1. Financial figures are being withheld upon request of the owner.

The continuation of this report will cover all of the above elements of this project and more in greater detail.

West Village Housing Phases III & IV

Located in: Towson, MD

Project Team

Owner	Towson University
General Contractor and CM	Whiting Turner Contracting
Architect & Landscape Architect	Ayers/Saint/Gross
Civil Engineer	Site Resources
Structural Engineer	Hope Furrer Associates
MEP/FP Engineers	Newcomb & Boyd
Electrical/Plumbing	WFT Engineering

Architecture

These two high-rise apartment buildings will add approximately 700 student beds to Towson University's campus. Floor arrangements included a mix of two and four bedroom apartments with shared bathrooms, kitchen and living areas creating an adult living environment to the students. The exterior façades are a mix of brick and steel plate veneers which will add personality to the area.

Construction

The buildings began construction simultaneously in September of 2014 to address the continued demand for on-campus housing and are planned to be finished in the summer of 2016.

Sustainability

Similar to most buildings on Towson University's campus, these two new facilities will be built in adherence with sustainable design and are expected to achieve LEED Silver certification.

Central lawn adjacent to building

General Information

Building occupant name	Towson University Students
Occupancy	Residence Hall
Size	170,000 sq. ft.
Full Height	92 ft.
Total number of stories	9
Date of construction	September 2014 - July 2016
Cost information	Figures are being withheld
Delivery method	CM at risk

Birds-eye view of project site

Electrical/Lighting Systems

Generally, interior lighting consists of fluorescent type T5. Downlights and decorative fixtures will be LED. Normal power for the building will originate from a pad-mount service transformer located outside each building.

Mechanical Systems

The heating is provided by a hot water system that consists of two boilers, hot water pumps, and piping. The hot water plant will be located in the penthouse on the roof. Chilled water will be distributed to coils in individual fan coil units via vertical distribution for each suite. Energy Recovery Units (ERU) will be single-zone medium pressure type to provide air conditioning. In addition, all units have occupant operable windows.

Structural Systems

<u>Framing</u> ------------The structural system will be 8" thick two-way post-tensioned concrete flat plats supported by reinforced concrete columns.

<u>Foundations</u>--------In order to utilize conventional spread footings, Rammed Aggregate Piers (RAPs) will be used.

<u>Lateral System</u>---12" thick concrete shear walls will effectively resist the forces imposed on the building from wind and seismic loading.

For more information, visit my CPEP site
http://mab6037.wix.com/thesis

Mark Bland [Structural Option]
Advisor: Dr. Aly Said

Table of Contents

1 General Information

1.1 Purpose and Scope

The objective of this report is to perform a detailed analysis of Townson University's, West Village Housing Phases III & IV North building to determine the loading conditions of the building.

This report will include an overview of the site location and plan. It will discuss and present calculations regarding the gravity, wind, and seismic loads applied to the building. A list of relevant resource documents used in design are also presented.

The knowledge documented in this report will be used as reference in future technical reports.

1.2 Site Location and Plan

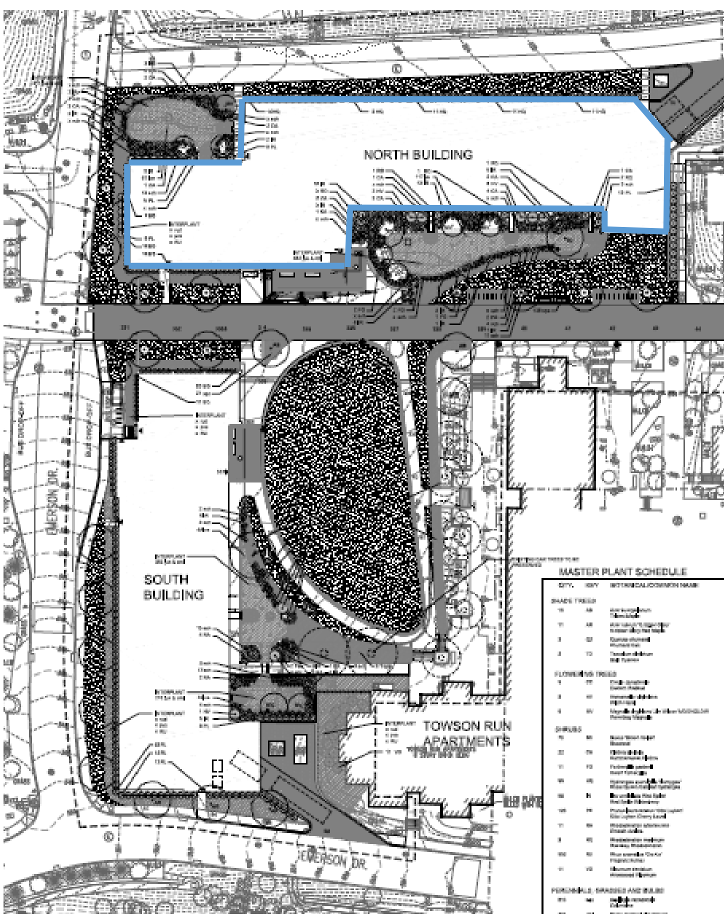


Figure 1: Site Landscaping

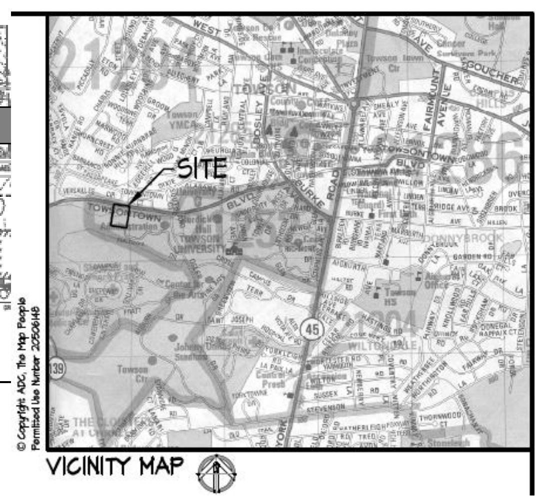


Figure 2: Vicinity Map

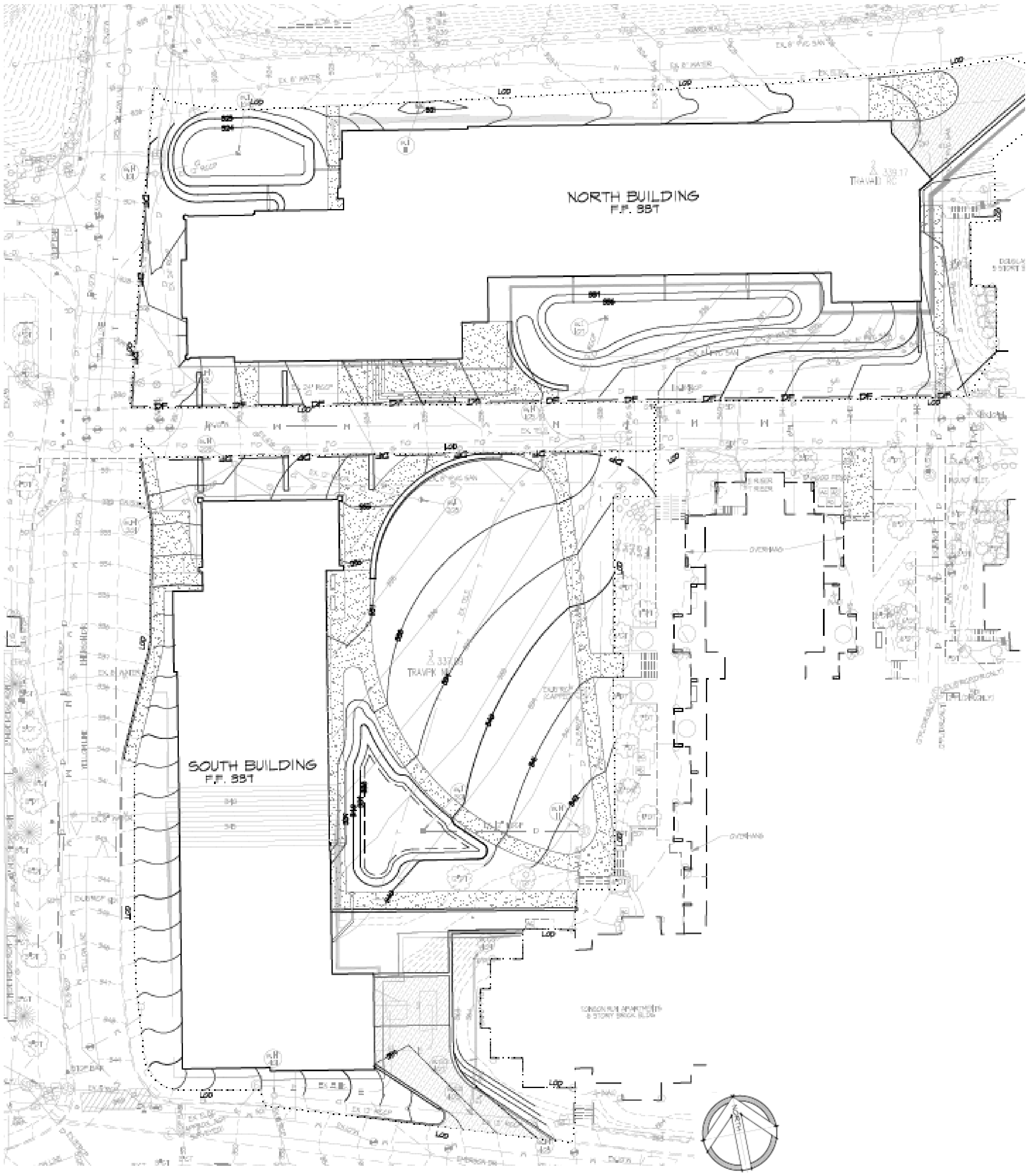


Figure 1: General Grading Plan

1.3 Documents Used During Preparation of Report

The following is a list of the design codes, standards or other references used on the project. These codes will be used to structurally analyze the loads on the structure of the West Village Housing Phases III & IV North building.

International Code Council

- International Building Code, 2012 Edition
- International Building Code, 2006 Edition
    - Used for drift and sliding snow loads only

American Society of Civil Engineers

- ASCE 7-10: Minimum Design Loads for Building and Other Structures

West Village Housing Phases III & IV

- Construction Drawings
- Specifications and details
- Correspondence with Project Engineers

Previous Course and Internship Notes/Resources

2 Gravity Loads

The gravity load calculations include dead, live and snow loads. The calculated loads will be compared to the actual loads used in the design of the building.

2.1 Dead and Live Loads

Figures 2 and 3 are sections taken from the architectural drawings on this project. Both are used to determine the composition of the component inorder to calculate the dead and live loads for the typical roof construction, floor construction and exterior wall construction. A typical floor cross section is provided in the calculations due to its absence in the drawings.

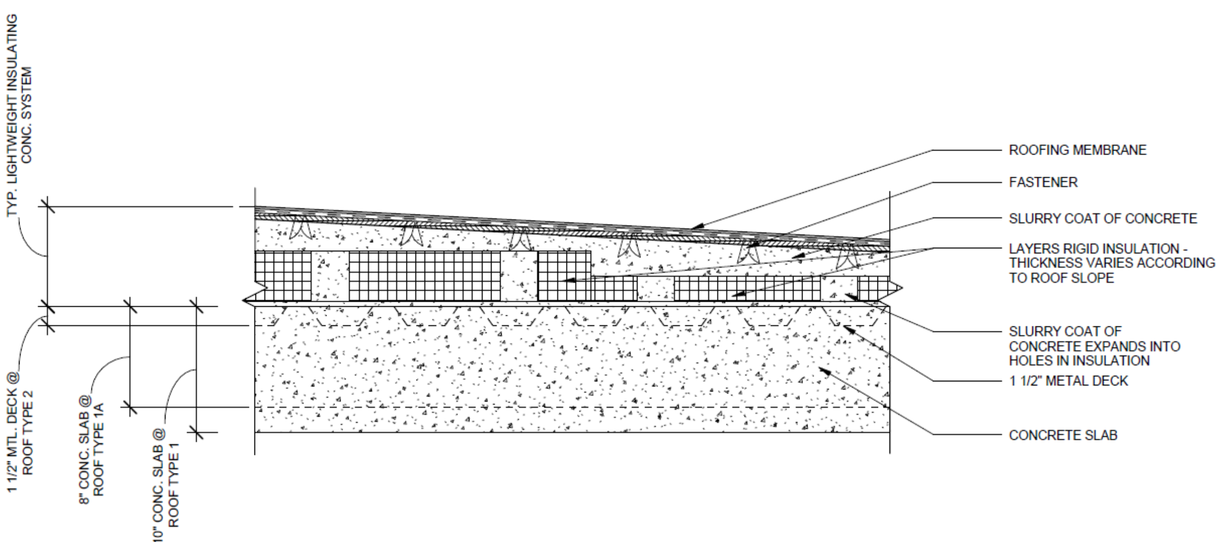


Figure 2: Typical roof bay cross section

Typical Roof Bay

Dead Load:

- Roofing membrane	=	3 PSF
- Rigid Insulation	=	1.5 psf (4") = 6psf → thickness
- 8" Concrete slab	=	12.5 PSF (8") = 100 Psf varies w/ slope
- 1½" metal deck	=	2 PSF
- MEP	=	3 PSF
- Ceilings (lighting/electrical)	=	5 PSF
- Collatoral	=	6 PSF

Total = 125 PSF

This is equivalent to loads specified on S1.00

Roof Live:

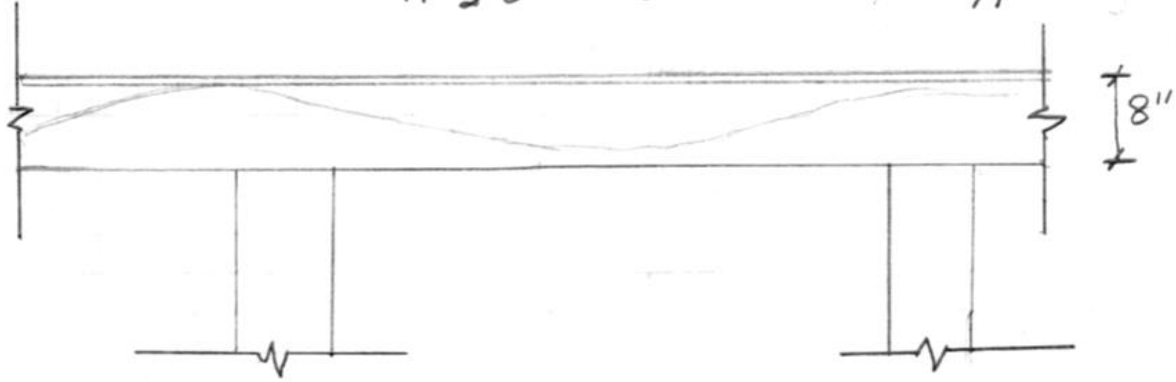
- 20 PSF per ASCE 7-10 table 4-1

* The Engineer chose to increase the minimum live load, provided in ASCE 7-10, to 30 psf. This may have been to a number of possible factors such as: roof maintenance, foot traffic

* Another portion of the roof does not have metal decking but has 10" of concrete slab. This dead load would be 148 PSF

Typical Floor Bay

- Floor consists of 8" thick post-tensioned concrete slab reinforced with ½" diameter tendons & typical reinf.



Dead load:

- 8" concrete = 125 psf (8") = 100 psf
- Floor finish = 2 psf
- MEP = 6 psf

Total = 108 psf

Live load:

- Private rooms and corridors serving them = 40 psf per ASCE 7-10 table 4-1
- Partitions = 15 psf

Total = 55 psf

* Note that live load for corridors and public spaces is equal to 100 psf

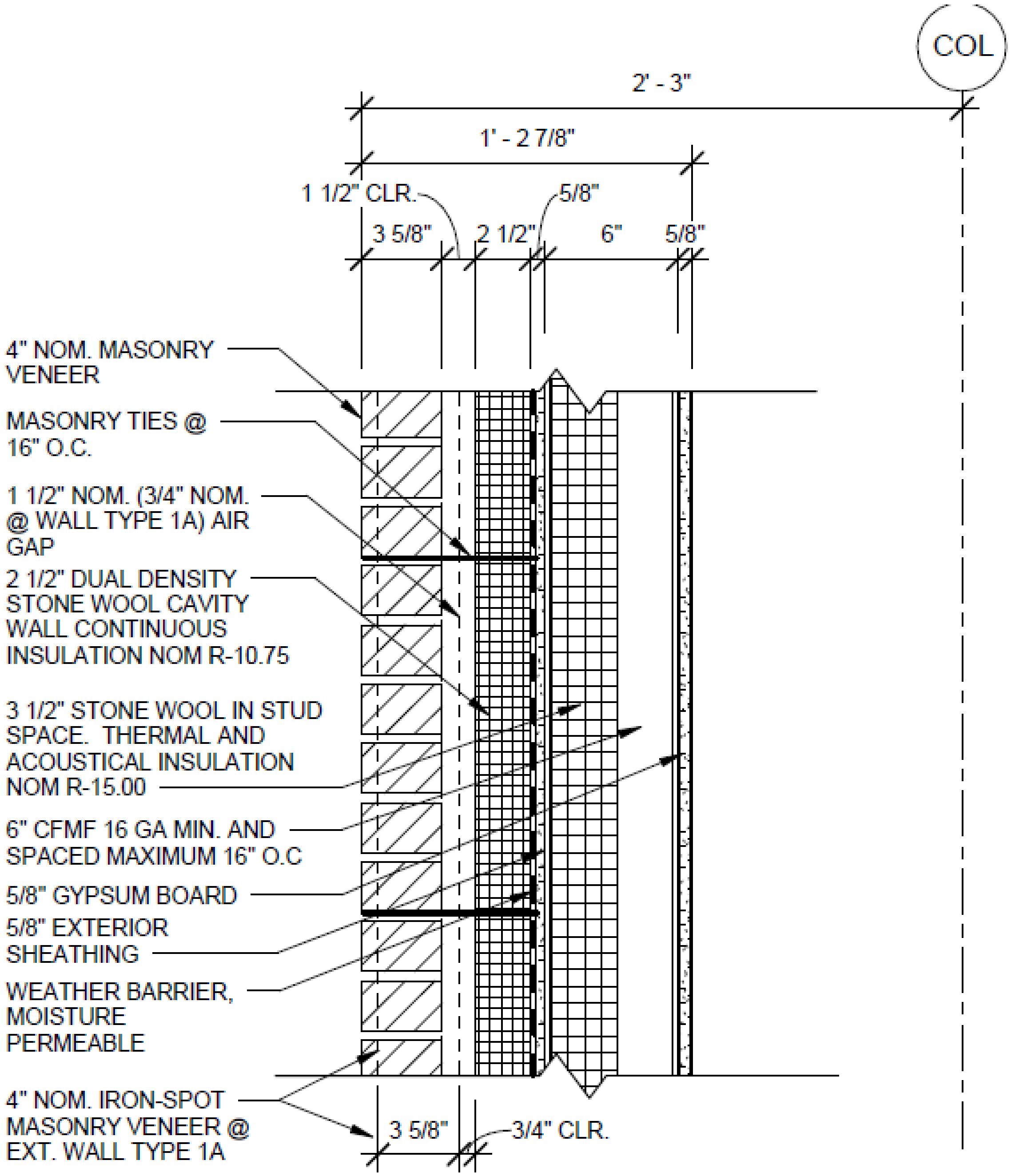


Figure 3: Typical Exterior Wall Detail

Typical Exterior Wall

Dead load:

- 4" veneer brick	= 38 psf
- 2½" insulation	= 3 psf
- 5/8" sheating	= 3 psf
- 6" metal studs	= 3 psf
- 5/8" gypsum board	= 3 psf
- collatoral	= 2 psf
Total	= 52 psf

Steel relieving angles are provided at each floor level to support exterior brick veneer. The weight of the typical exterior brick wall is taken by the angle, and transferred into the concrete floor system. This load is tranferred to the columns and then down to the foundation

Non Typical Dead Loads

- Store front curtain wall system (level 1) = 10 psf

- Exterior wall with metal paneling (not as large as brick) = 25 psf

- Penthouse floor = 150 psf
  Design values based on equipment weight ranging from 11,000 lbs – 19,000 lbs

Non Typical Live Loads

- Penthouse Floor = 100 psf
  Due to heavier mechanical roof traffic

Snow load Calculations

Flat roof snow load: using ASCE 7-10

$P_f = 0.7 C_e C_t I P_g$ (eq 7.3-1)

$P_g = 25psf$ (Figure 7-1)
$C_e = 0.9$ (Table 7-2)
$C_t = 1.0$ (Table 7-3)
$I = 1.0$ (Table 1.5-2) category II

$P_f = 0.7(0.9)(25) = \underline{15.75psf}$

Snow Drift

-calculated for drift from mechanical penthouse roof

$h_b = \frac{P_s}{\gamma}$ $P_s = P_f = 15.75psf$

$h_b = \frac{P_s}{0.13P_g + 14} = \frac{15.75}{0.13(25)+14} = 0.91$

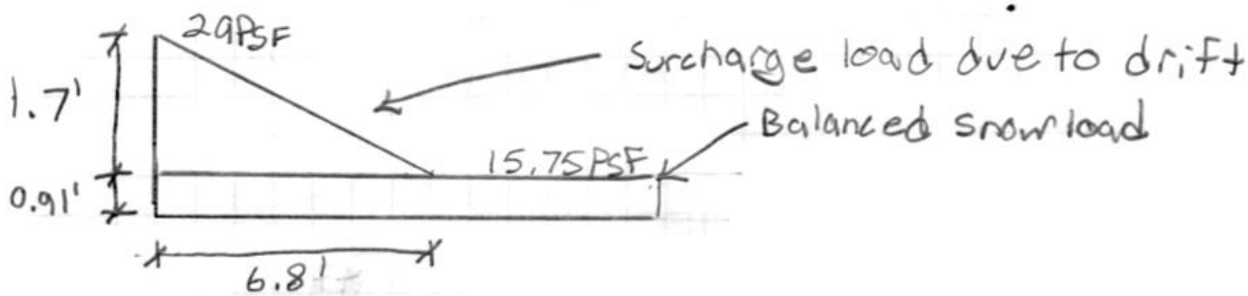
$h_c = 11' - 1' = 10'$ $h_c/h_b > 0.2 \rightarrow$ drift load must be calculated

$l_u = 28.3'$

Leeward:
$h_d = 1.7$ (Figure 7-9)
$h_d < h_c$, ∴ $w = 4h_d = 6.8ft$

Windward:
$h_d = 3/4(1.7) = 1.3ft < 1.7ft$ ∴ use $h_d = 1.7ft$

$P_d = h_d \gamma$
$= 1.7(0.13(25)+14) = 29psf$



3 Wind Loads

This section provides an overview of the wind loads considered for design. Tables 1 and 2 show the total windward and leeward pressures experienced on the building in both the E-W and N-S directions. Following these tables are hand calculations showing the wind load procedure found in ASCE 7-10 section 26. The calculations evaluate the North building residence hall. This includes 8 residence levels with a smaller penthouse at the lower roof level.

3.1 Calculations

Table 1: Wind Force Determination E-W

Building Level	Height above ground level z (ft)	K_z	q_z	$p_{z(W)}$	$p_{h(L)}$	Total (psf)
Level 1	0.0	0.575	16.54	10.59	-11.11	21.70
Level 2	12.0	0.575	16.54	10.59	-11.11	21.70
Level 3	21.3	0.635	18.28	11.70	-11.11	22.81
Level 4	30.7	0.705	20.29	12.99	-11.11	24.10
Level 5	40.0	0.761	21.89	14.01	-11.11	25.12
Level 6	49.3	0.807	23.24	14.87	-11.11	25.98
Level 7	58.7	0.849	24.42	15.63	-11.11	26.74
Level 8	68.0	0.885	25.47	16.31	-11.11	27.42
Lower Roof	78.8	0.923	26.57	17.01	-11.11	28.12
PH Roof	86.7	0.949	27.30	17.48	-11.11	28.59

Table 2: Wind Force Determination N-S

Building Level	Height above ground level z (ft)	K_z	q_z	$p_{z(W)}$	$p_{h(L)}$	Total (psf)
Level 1	0.0	0.575	16.54	11.25	-4.72	15.97
Level 2	12.0	0.575	16.54	11.25	-4.72	15.97
Level 3	21.3	0.635	18.28	12.43	-4.72	17.15
Level 4	30.7	0.705	20.29	13.80	-4.72	18.52
Level 5	40.0	0.761	21.89	14.88	-4.72	19.60
Level 6	49.3	0.807	23.24	15.80	-4.72	20.52
Level 7	58.7	0.849	24.42	16.61	-4.72	21.33
Level 8	68.0	0.885	25.47	17.32	-4.72	22.04
Lower Roof	78.8	0.923	26.57	18.07	-4.72	22.79
PH Roof	86.7	0.949	27.30	18.56	-4.72	23.28

Wind Load Calculations

1) Risk Category: (table 1.5-1)
   Category II
2) Basic wind speed, V: (Figure 26.5-1A)
   V = 115mph
3) Wind load parameters:
   - Wind directionality Factor, K_d (table 26.6-1)
     $K_d = 0.85$
   - Exposure Category (section 26.7)
     Exposure Category B
     * used by engineer
   - topographic Factor (table 26.8-1)
     $K_{zt} = 1.0$
     * building is not located on a ridge, escarpment or hill
   - Gust effect Factor (section 26.9)
     $T_a = \frac{0.0019}{\sqrt{C_w}} h_n$ (12.8-9) > 1
     ∴ use G = 0.85 enclosed building

   Internal Pressure Coefficients
   $GC_{pi} = \pm 0.18$

4) Velocity pressure exposure coefficient, K_z:
   - K_z varies w/ height (table 27.3-1)
     * see spreadsheet
5) Velocity pressure, q_z:
   $q_z = 0.00256 K_z K_{zt} K_d V^2$
   K_z = varies w/ height
   $K_{zt} = 1.0$
   $K_d = 0.85$
   $V = 115mph$

   $q_z = 0.00256 K_z (1.0)(0.85)(115)^2 = 28.78 K_z$
   * see spreadsheet for values of q_z

6) External pressure Coefficient, C_p:

North-South: $\frac{L}{B} = \frac{300'}{61'} = 4.9$

East-West: $\frac{L}{B} = \frac{61'}{300'} = 0.69$

Walls: - windward $C_p = 0.8$
- Leeward $C_p = -0.2$ in N/S, $C_p = -0.5$ in E/W
- side wall $C_p = -0.7$

Roofs: - Flat roof, $\theta = 0$

$h/L < 0.5$ — horizontal distance from windward edge $= 300' > 2h$

$C_p = -0.3, -0.18$

7) Wind pressure

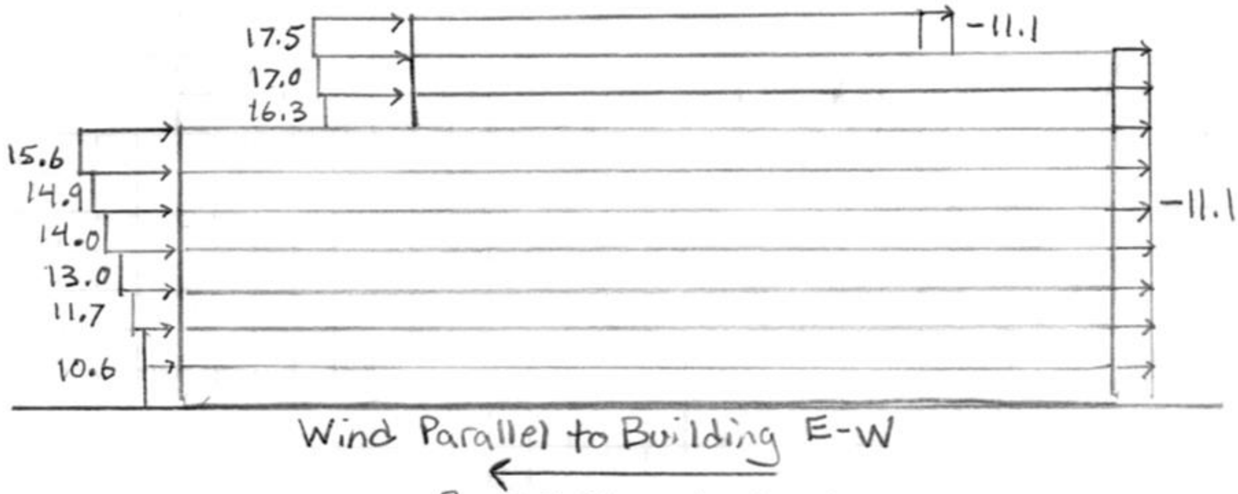
$p = q G C_p - q_i (G C_{pi})$ (27.4-1)

* see spreadsheet for p values

Table 3: Base Shear Determination E-W				
Building Level	**Height above ground level z (ft)**	**Tributary Height (ft)**	**Total Pressure (psf)**	**Total Lateral Story Force (kip)**
Level 1	0.0	6.00	21.70	**39.06**
Level 2	12.0	10.65	21.70	**69.32**
Level 3	21.3	9.34	22.81	**63.89**
Level 4	30.7	9.35	24.10	**67.59**
Level 5	40.0	9.32	25.12	**70.20**
Level 6	49.3	9.34	25.98	**72.77**
Level 7	58.7	9.35	26.74	**75.01**
Level 8	68.0	10.08	27.42	**82.90**
Lower Roof	78.8	9.34	28.12	**78.75**
PH Roof	86.7	3.92	28.59	**33.62**
Total Base Shear (kips) =				**653.11**

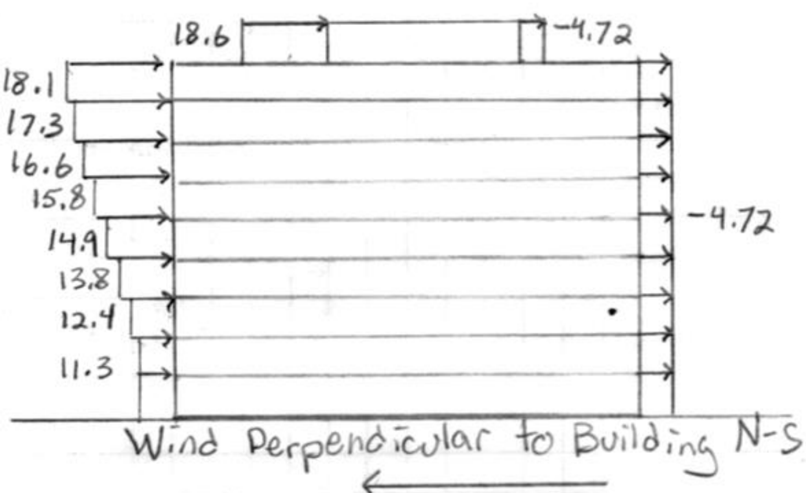
Table 4: Base Shear Determination N-S				
Building Level	**Height above ground level z (ft)**	**Tributary Height (ft)**	**Total Pressure (psf)**	**Total Lateral Story Force (kip)**
Level 1	0.0	6.00	15.97	**5.84**
Level 2	12.0	10.65	15.97	**10.37**
Level 3	21.3	9.34	17.15	**9.77**
Level 4	30.7	9.35	18.52	**10.56**
Level 5	40.0	9.32	19.60	**11.14**
Level 6	49.3	9.34	20.52	**11.69**
Level 7	58.7	9.35	21.33	**12.16**
Level 8	68.0	10.08	22.04	**13.55**
Lower Roof	78.8	9.34	22.79	**12.98**
PH Roof	86.7	3.92	23.28	**5.57**
Total Base Shear (kips) =				**103.63**

Wind Diagrams (values in psf)



Wind Parallel to Building E-W

Base shear = 653.11 Kips



Wind Perpendicular to Building N-S

Base shear = 103.63 Kips

4 Seismic Loads

This section provides an overview of the seismic loads considered for design. Below is the standard procedure to calculate seismic loads which is in accordance with ASCE 7-10 section 11. The main lateral force resisting elements in the structure are ordinary reinforced concrete shear walls

4.1 Calculations

Seismic Load Calculations

1) Find mapped Acceleration Parameters:

$S_s = 0.175$ $S_1 = 0.051$

2) Site Classification:

Site Classification C (verified by geotechnical report)

3) Max Considered Spectral Response Acceleration Parameters:

$F_a = 1.2$ $F_v = 1.7$

$S_{MS} = F_a S_s = 1.2(0.175) = 0.21$

$S_{M1} = F_v S_1 = 1.7(0.051) = 0.087$

4) Design Spectral Parameters (11.4.4)

$S_{DS} = \frac{2}{3} S_{MS} = 0.14$

$S_{D1} = \frac{2}{3} S_{M1} = 0.058$

5) Importance Factor: $I_e = 1.0$ (1.5-2)

6) Risk Category: II (section 11.6)

7) Seismic Design Category: A (table 11.6-1)

Basic Seismic Force Resisting System

- Ordinary Reinforced Concrete shear walls

$R = 5$

$\Omega = 2\frac{1}{2}$ (table 12.2-1)

$C_d = 4\frac{1}{2}$

8) Analysis Procedure selection:

(Section 11.7) - Buildings with Seismic Design Category A are exempt from seismic Design Criteria and must only comply with section 1.4.

9) Lateral Forces:

$F_x = 0.01\ W_x$ (section 1.4.3)

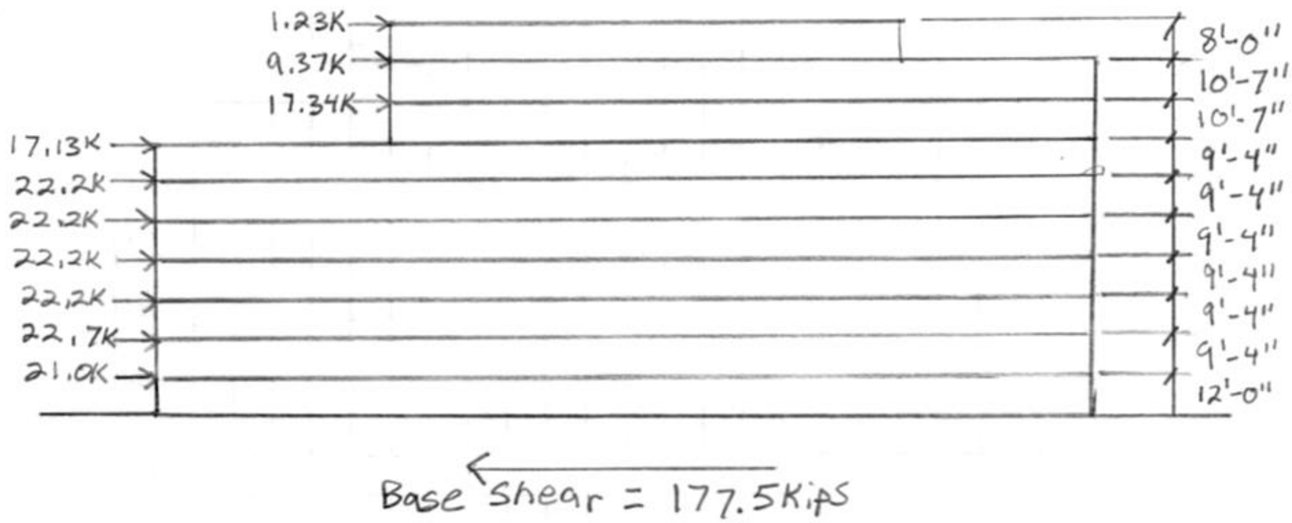
W_x = total dead load per story

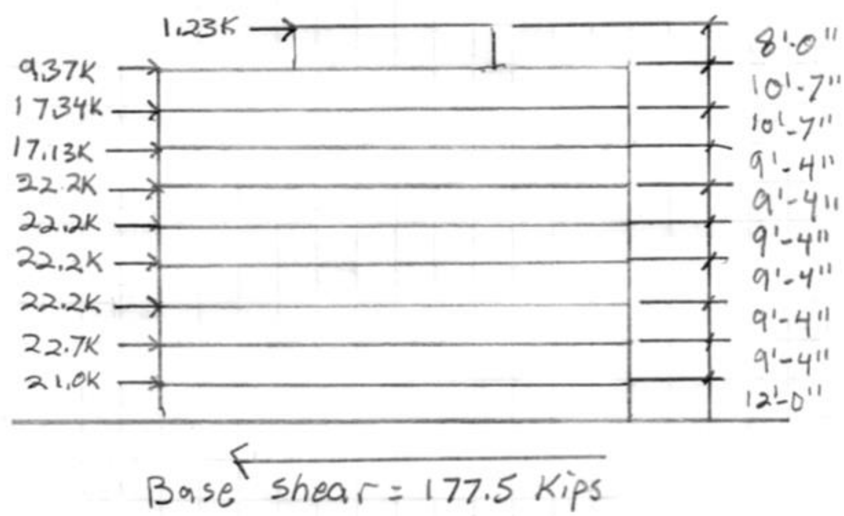
* see spreadsheet for floor weights and story forces.

Table 5: Seismic Load Determination									
Building Level	**Height above ground level z (ft)**	**Tributary Height (ft)**	**Total Floor Dead Load (psf)**	**Total Floor Area (s.f.)**	**Total Exterior Wall Load (psf)**	**Permiter (ft)**	**Total Story Weight W (kip)**		
Level 1	0.0	6.00	108	17400	52	700	2097.6	0.01	**20.98**
Level 2	12.0	10.65	108	17400	52	700	2266.9	0.01	**22.67**
Level 3	21.3	9.34	108	17400	52	700	2219.0	0.01	**22.19**
Level 4	30.7	9.35	108	17400	52	700	2219.5	0.01	**22.20**
Level 5	40.0	9.32	108	17400	52	700	2218.3	0.01	**22.18**
Level 6	49.3	9.34	108	17400	52	700	2219.0	0.01	**22.19**
Level 7	58.7	9.35	108	13320	52	564	1712.8	0.01	**17.13**
Level 8	68.0	10.08	108	13320	52	564	1734.2	0.01	**17.34**
Lower Roof	78.8	9.34	150	4928	52	408	937.3	0.01	**9.37**
PH Roof	86.7	3.92	25	4928	0	408	123.2	0.01	**1.23**
Total Base Shear (kips) =									**177.48**

*Exterior wall types vary throughout the building. In order to be conservative, the heaviest wall type (brick) will be used on all floors

Seismic Load vs Story Height





* With simplified method for buildings in a seismic design category A, the seismic story forces are the same in both directions.

5 Closing

The lateral system design of West Village Housing Phases III & IV north building is governed by wind forces. This was expected due to its location and size. The elongated shape of the building creates a large surface area for wind loads to be applied to. This is why the lateral forces due to wind were slightly larger than those due to seismic loads. As analysis progress, particular attention must be paid to the different exterior façades as well as the mechanical units in the penthouse.