September 27, 2013

Heather Sustersic
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Dear Professor Sustersic,

The following technical report was written to fulfill the requirements specified in the Structural Technical Report 2 assignment that was handed out on September 13, 2013.

Technical report 2 includes a detailed structural analysis of the New Library at the University of Virginia's College at Wise, located in Wise, Virginia. This analysis includes calculations of roof loads, floor loads, exterior wall loads, snow loads, snow drifts, wind pressures, and seismic story forces.

Thank you for reviewing this report. I look forward to discussing it with you in the future.

Sincerely,

Macenzie Ceglar

Enclosed: Technical Report 2

Technical Report 2

University of Virginia's College at Wise New Library

Macenzie Ceglar
Structural Option
Advisor: Heather Sustersic
27 September 2013

Executive Summary

The New Library at the University of Virginia's College at Wise will serve as a main link between the upper and lower campus areas, which are currently divided by a steep 60 foot hill. The new 6 story, 68,000 ft^2, library will be integrated into the hillside, and will provide students with an easier and safer path across campus. The architectural design of the façade incorporates traditional materials found on campus, such as brick and stone. Construction on the New Library began in August 2012 and will be completed in August 2015.

Soil loads caused the foundation system for the New Library to be unique in its design. The foundation system utilizes a temporary leave-in-place soil retention system and foundation walls which are designed to resist future lateral soil loads. Other parts of the foundation system include piers, footings, and slabs-on-grade.

All six stories of the building have composite floor framing involving both composite steel wide flange members and composite decking. Framing layout in the building is fairly typical with bay sizes ranging between 25'-4" x 25'4" and 31'-0" x 25'-4". Steel wide flange columns are used as the vertical framing system and shear walls make up the building's lateral system.

Loading conditions considered in the building's design include live loads, gravity loads, snow loads, wind loads, seismic loads, and lateral soil loads.

The Virginia Uniform Statewide Building Code (USBC); along with "Facility Design Guidelines", governs the design of all buildings on the campus. The USBC adopts chapters 2-35 of International Building Code (IBC) 2009, which references codes and standards which include American Society of Civil Engineers (ASCE) 7-05, American Concrete Institute (ACI) 318-08, and the 13th edition of the Steel Construction Manual.

Table of Contents

University of Virginia's College at Wise - New Library

Wise, VA

General Information

Full Height: 119'
Number of Stories: 6
Size: 68,000 SF
Cost: $43 Million
Date of Construction: August 2012 – August 2015
Project Delivery Method: Design-Bid-Build

Project Team

Owner:	UVA at Wise
Architect:	Cannon Design
Structural:	Cannon Design
MEP:	Thompson and Litton
Lighting Consultant:	Lafleur Associates
Construction:	Quesenberrys, Inc.
Civil:	Thompson and Litton
Landscape:	Hill Studio
AV/Acoustics:	Shen Milsom Wilke
Foodservice Design:	Culinary Advisors

Structural Systems

Foundation:	Slab on grade with column piers, footings and foundation walls
Framing:	Steel frame, composite wide flange steel members, and normal weight composite deck flooring
Lateral:	9 Reinforced concrete shear walls
Soil Retention:	Temporary Leave-In-Place Soil Retention System

Mechanical

VAV system with a roof mounted chilled-water air handling unit with a 145.9 ton chiller providing 41,300 CFM and a heat recovery unit

Electrical/Lighting

Five 480/277 3-phase panel boards
Nine 280/120 3-phase panel boards

Wall switch and low voltage occupancy sensors used for lighting control

Architecture

The building's design was to bring a sense of cohesion to the existing buildings, as it is to be located directly between the existing upper and lower campuses. The goal was to give the impression that the older existing buildings' architecture was based on the New Library's. This was achieved through use of materials such as brick and stone commonly found on the surrounding buildings.

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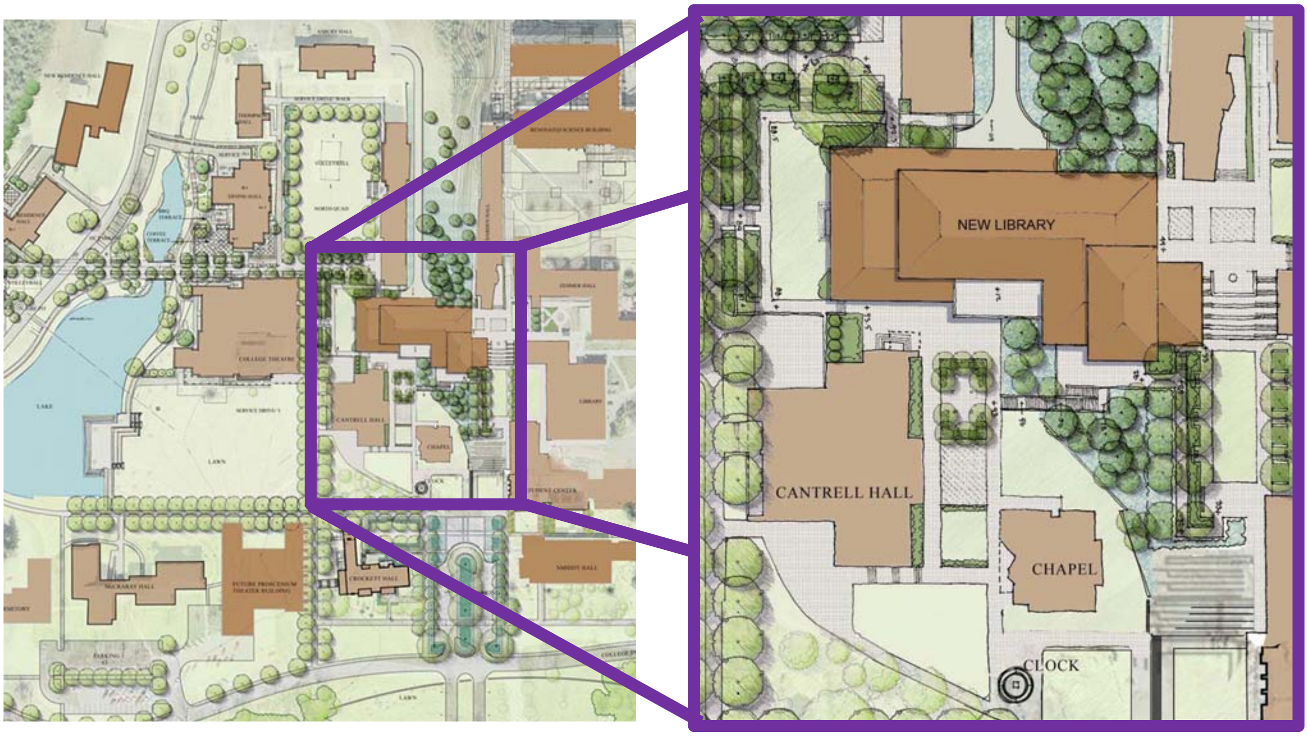
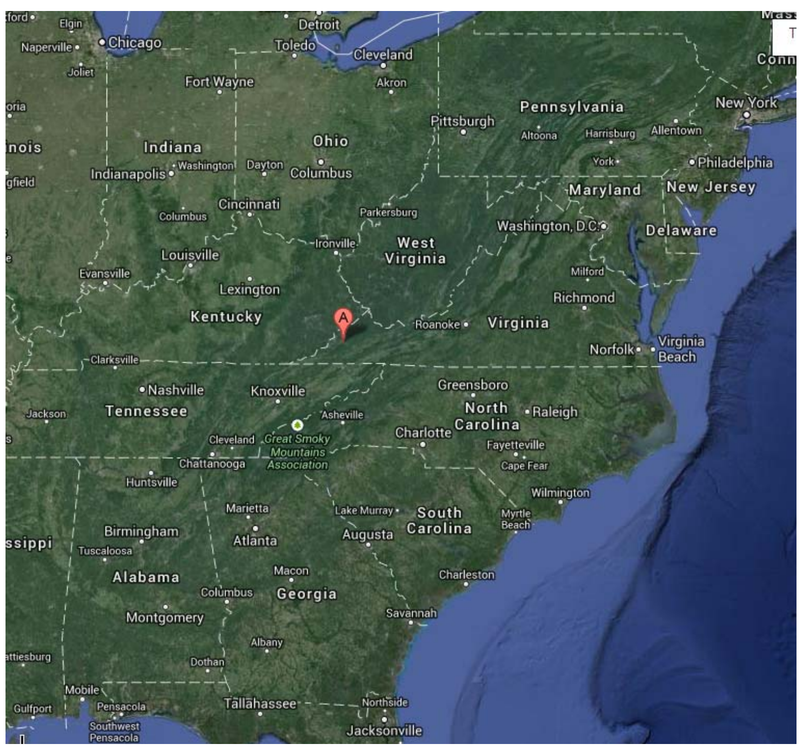
www.engr.psu.edu/ae/thesis/portfolios/2014/mac5676/index.html

Site Plan



Location Plan



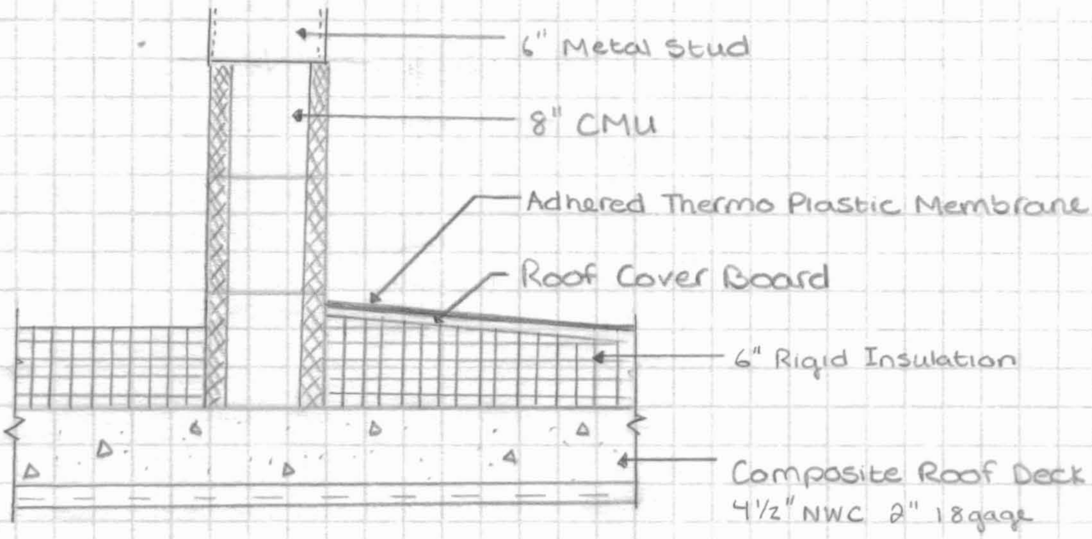
Documents Used in Preparation of Report

Below is a list of the design codes and standards used in the structural analysis of the New Library at the University of Virginia's College at Wise.

- **International Code Council**
  - International Building Code 2009 (Chapters 2-35 Adopted by Virginia Uniform Statewide Building Code)
- **American Society of Civil Engineers**
  - ASCE 7-05: Minimum Design Loads for Buildings and Other Structures
- **University of Virginia Facilities Management and University Building Official**
  - Facility Design Guidelines
- **University of Virginia's College at Wise – New Library**
  - Construction Documents
  - Specifications
- **Vulcraft Deck Catalog**

Typical Roof Bay Dead Loading

Cross section of lower roof construction



Uniformly Distributed Dead Loads

Composite roof deck = 69 psf

6" Rigid Insulation = 9 psf

Roof cover board = 2 psf

Adheared Membrane = 2 psf

Superimposed misc:

Ceiling = 5 psf

Mechanical = 10 psf

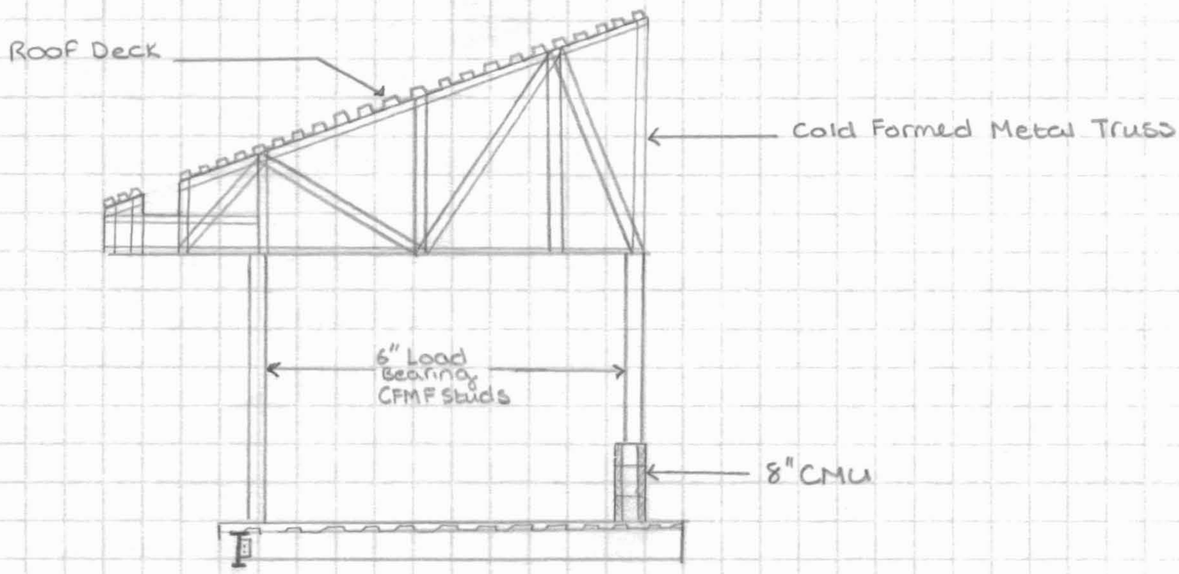
Sprinklers = 10 psf

Framing Alowance = 10 psf

Total = 117 psf

Distributed Line Loads on Roof

Cross section of upper roof construction



Distributed line load from CMU wall bearing trusses

Cold Formed Metal Trusses = 2psf

Spacing = 12" o.c.

Truss Length = 23.1'

2psf x 23.1 = 46.2 plf

Load on CMU wall = $\frac{46.2}{2}$ = 23.1 plf

8" CMU = 55psf

wall height = 2ft

Load from CMU wall = 55 x 2 = 110 plf

Total = 133.1 plf

Typical Roof Bay Live Loading

LOADS	Design Value	Code Minimum
Minimum Roof Live Load	30 psf	20 psf
Roof Area Below Sloped Roof	30 psf	-
Roof Mechanical Area	150 psf	-

Reason for Differences

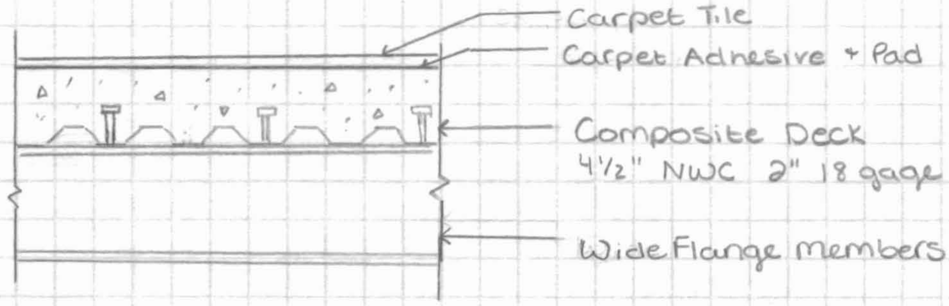
Minimum Roof Live Load: UVA Facility Guidelines specifies a minimum roof live load which overrules ASCE7-05

Roof Area Below Sloped Roof: unlikely that this area will see a live load so a minimum was used

Roof Mechanical Area: Final mechanical system was unknown so design team provided a large enough allowance

Typical Floor Bay Dead Loading

Cross Section of Floor Calculation



Uniformly Distributed Dead Loads

Composite Deck = 69 psf

Carpet Tile = 1 psf

Pad + Adhesive = 0.5 psf

Super imposed misc:

Ceiling = 5 psf

Mechanical = 10 psf

Sprinklers = 10 psf

Framing Allowance = 10 psf

Total = 105.5 psf

Non-Typical Dead Loads

Loads	Location	Value	Justification
Roof Deck 1½" 20gage	upper roof	2.16 psf	Vulcraft Catalog Pg 9 (1.5A Roof Deck)
Composite Deck 8½" NWC 2" 18g	Level 4 supporting vestible area	105 psf	Vulcraft Catalog Pg 52 (6psf / 0.5" of topping)
3/16" Terrazzo Tile 24" x 24"	Level 4 vestible and in Stair wells	2 psf	ASCE 7-10 Pg 402

Typical Floor Bay Live Loading

Loads	Design Value	Code Minimum	Justification
Offices	50	50	ASCE7-05
Corridor (Not First Floor)	80	Same as area served	Office + Partitions ≃ 80
Partitions	27	–	Cannon Design Standard

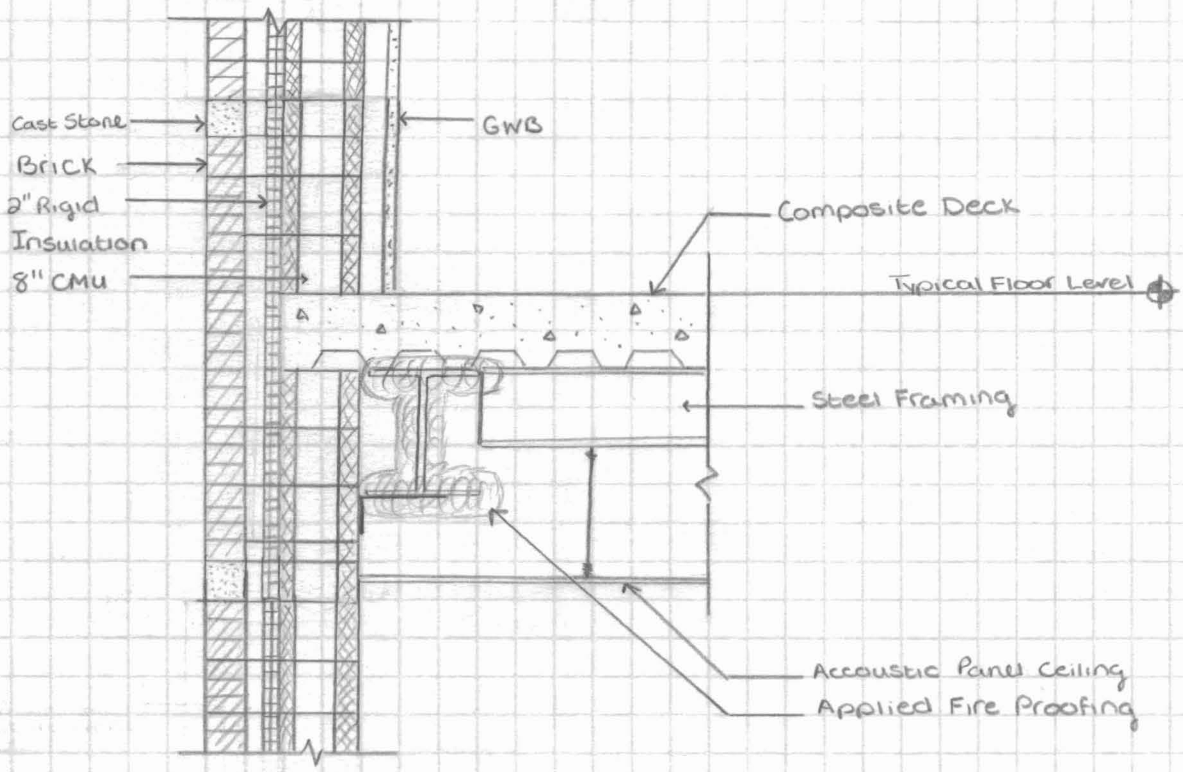
⇒ These loads pertain to the typical bay specified in Technically Report 1. They are found in a large majority of the building. Library stacks make up a large part of the live loading, but are not located in the specified bay.

Non-Typical Live Loads

Loads	Location	Design Value	Code Min.	Justification
Library Stack Rooms	Level 2,3,4,5,6 in various locations	150psf	150psf	ASCE 7-05
Mechanical Rooms	Level 2, lower roof	250psf	–	Industry standard for heavy Equipment
High Density Storage	Level 1	250psf	250psf	ASCE 7-05
Stairs	center, east corner, and south corner of building	100psf	100psf	ASCE 7-05

Typical Exterior Wall Loading

Cross Section of Typical Exterior Wall



Wall Loads (loads provided by cannon design)

Brick + 8" CMU = 95psf x 16' (typical floor-to-floor height) = 1520 plf

2" rigid insulation = 3 psf x 16' = 48 plf

Water proofing Allowance = 1 psf x 16' = 16 psf

Total = 1584 plf

Load Path

The load due to the exterior wall is carried by the edge of the composite deck. The deck transfers the load to the wide flange members which then transfers the load into steel columns. From there the load is transferred to the foundation and discipated into bedrock.

Snow Loads

Lower Roof - Flat

$P_f = 0.7 C_e C_t I p_g$

$C_e = 1.0$ (Partially Exposed Roof, Exposure B)

$C_t = 1.0$

$I = 1.1$ (Occupancy Catagory 3)

$P_g = 30$ psf

$P_f = 0.7(1.0)(1.0)(1.1)(30) = 23.1$ psf

Upper Roof - Sloped

$P_s = C_s P_f$

$C_e = 1.0$ (contains large mechanical equipment)

$C_t = 1.1$

$I = 1.1$

$P_g = 30$

$P_f = 0.7(1.0)(1.1)(1.1)(30) = 25.4$ psf

$C_s = 1.0$ (cold roof, roof surface obstructed)

$P_s = 1.0(25.4) = 25.4$ psf

⇒ Design was conservative and used a design snow load of 26 psf for both the lower flat roof and upper sloped roof.

Snow drifts are calculated for the smaller roof section on the west (true North-west) end of the building and for drifts that may occur on the interior of the upper roof.

Lower Roof

Determine if snow drift calculation is required

If $h_c/h_b < 0.2$ drift loads not applicable

$h_c = 51.9'$ (measured from balanced snow load to top of exterior wall along Column Line 3)

$h_b = p_s/\gamma$

$p_s = 26\text{psf}$ (see snow load calc)

$\gamma = 0.13p_g + 14 < 30\text{pcf}$
$= 0.13(30) + 14$
$= 17.9\text{ pcf}$

$= 26/17.9 = 1.45\text{ ft}$

$h_c/h_b = 51.9/1.45 = 35.79 > 0.2$

⇒ Snow drifts must be considered

Leeward

h_d:

$p_g = 30$
$l_u \Rightarrow 147$

$h_d = 4$

Windward

h_d:

$p_g = 30$
$l_u = 25'4''$

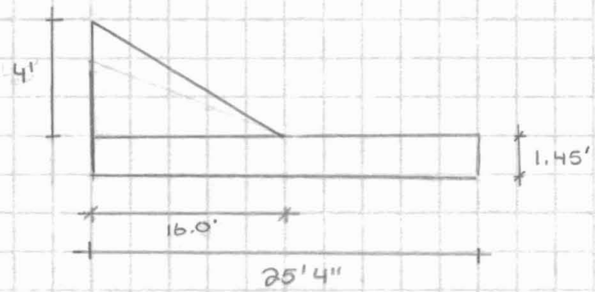
$h_d = \frac{3}{4}(1.5) = 1.125\text{ ft}$

⇒ The larger h_d shall be used in design ⇒ 4 ft

Lower Roof Cont

$h_d = 4\ ft < h_c = 53'4''$

$w = 4h_d = 4(4) = 16$



Snow drift on interior walls of fake Mansard Roof

$h_c = 16'11''$
$h_b = 1.45$

$h_c / h_b = 16'11'' / 1.45 = 11.67 > 0.2$ ⇒ Snow drift must be considered.

leeward

h_d:

$p_g = 30$
$l_u = 25$ ⇒ no roof upwind of drift so $l_u = 25ft$ used per Figure 7-9.

$h_d = 1.5\ ft$

windward (worst case ⇒ largest l_u)

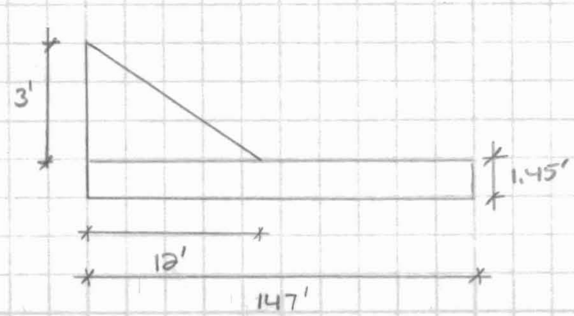
h_d:

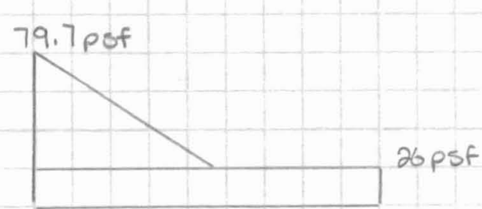
$p_g = 30$
$l_u = 147$

$h_d = 3/4(4) = 3$

$h_d = 3\ ft < 16'11''$

$w = 4(3) = 12'$





Wind Load Calculation

⇒ ASCE 7-05 Chapter 6.5 Method 2 - Analytical Method

1. Occupancy Category (Table 1-1)

   ⇒ III [Buildings and other structures with a capacity greater than 500 for colleges or adult educational facilities]

2. Determine the wind load importance factor (Table 6-1)

   ⇒ $I = 1.15$ [Occupancy Catagory III, non-hurricane prone]

3. Determine Basic Wind Speed (Fig 6-1)

   ⇒ $V = 90$ MPH

4. Determine Wind Load Parameters

   a. Wind Directionality Factor K_d (Table 6-4)

      ⇒ $K_d = 0.85$

   b. Exposure Catagory (6.5.6.3)

      ⇒ B

   c. Topographic Factor, K_{zt} (Fig 6-4)

      ⇒ 1.0

   D. Gust Effect Factor G (6.5.8)

      i) Determine natural frequency, n_a (C6.5.8)

      - Building meets requirements
        ① Building height < 300ft
        ② Building height < $4L_{eff}$

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

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

Shear wall 1 (At CL 6.8) - NS

$A_B \cong (173' \times 51') + (42' \times 72') = 11,847\ ft^2$

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 14' = 14\ ft^2$

$D_i = 14'$

$$\left(\frac{102}{102}\right)^2 \frac{14}{\left[1 + 0.83\left(\frac{102}{14}\right)^2\right]} = 0.311$$

Shear Wall 2 (At CL B.2) - EW

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 21' = 21\ ft^2$

$D_i = 21'$

$$\left(\frac{102}{102}\right)^2 \frac{21}{\left[1 + 0.83\left(\frac{102}{14}\right)^2\right]} = 0.466$$

Shear Wall 3 (At west stair wall) - NS

$H = 102'$

$h_i = 68$

$A_i = \frac{12''}{12} \times 8.6' = 8.6\ ft^2$

$D_i = 8.6'$

$$\left(\frac{102}{68}\right)^2 \frac{8.6}{\left[1 + 0.83\left(\frac{68}{8.6'}\right)^2\right]} = 0.366$$

Shear Wall 4 (At South Stair wall) - EW

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 20.33' = 20.33\ ft^2$

$D_i = 20.33'$

$$\left(\frac{102}{102}\right)^2 \frac{20.33}{\left[1 + 0.83\left(\frac{102}{20.33}\right)^2\right]} = 0.929$$

Shear Wall 5 (At CL5) - NS

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 12' = 12ft^2$
$D_i = 12'$

$$\left(\frac{102}{102}\right)^2 \frac{12}{\left[1+0.83\left(\frac{102}{12}\right)^2\right]} = 0.197$$

Shear Wall 6 (At CL D) - EW

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 25.2 = 25.2ft^2$
$D_i = 25.2'$

$$\left(\frac{102}{102}\right)^2 \frac{25.2}{\left[1+0.83\left(\frac{102}{25.2}\right)^2\right]} = 1.726$$

Shear Wall 7 (At CL 4) - NS

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 20' = 20ft^2$
$D_i = 20'$

$$\left(\frac{102}{102}\right) \frac{20}{\left[1+0.83\left(\frac{102}{20}\right)^2\right]} = 0.885$$

Shear Wall 8 (At East Stair Wall) - NS

$H = 102'$
$h_i = 34'$
$A_i = \frac{12''}{12} \times 10' = 10ft^2$
$D_i = 10'$

$$\left(\frac{102}{34'}\right)^2 \frac{10}{\left[1+0.83\left(\frac{34}{10}\right)^2\right]} = 8.495$$

Shear Wall 9 (At CL E) - EW

$H = 102'$
$h_i = 34'$
$A_i = \frac{12''}{12} \times 23.3' = 23.3 ft^2$
$D_i = 23.3'$

$$\left(\frac{102}{34}\right)^2 \frac{23.3}{\left[1 + 0.83\left(\frac{34}{23.3}\right)^2\right]} = 75.776$$

North - South

$$\sum \left(\frac{H}{h_i}\right)^2 \frac{A_i}{\left[1+0.83\left(\frac{h_i}{D_i}\right)^2\right]} = 0.311 + 0.366 + 0.197 + 0.885 + 8.495$$
$$= 10.254$$

$$C_{w,NS} = \frac{100}{11,847}(10.254) = 0.0866$$

$$n_{a,NS} = 385(0.0866)^{0.5}/102 = \underline{\underline{1.11 \text{ Hz}}}$$

East - West

$$\sum \left(\frac{H}{h_i}\right)^2 \frac{A_i}{\left[1+0.83\left(\frac{h_i}{D_i}\right)^2\right]} = 0.466 + 0.929 + 1.726 + 75.776$$
$$= 78.897$$

$$C_{w,EW} = \frac{100}{11,847}(78.897) = 0.6660$$

$$n_{a,EW} = 385(0.6660)^{0.5}/102 = \underline{\underline{3.08 \text{ Hz}}}$$

$\Rightarrow n_a > 1.0$ Hz in both directions $\Rightarrow$ Rigid Structure

ii) Rigid Buildings (6.5.8.1)

$$G = 0.925\left(\frac{(1+1.7 g_Q I_{\bar{z}} Q)}{1+1.7 g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$
$g_v = 3.4$

$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.30\left(\frac{33}{0.6(102)}\right)^{1/6} = 0.271$$ * $\bar{z} > z_{min} = 30'$

N-S Direction ⇒ $$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$$

$B = 147'$
$h = 83.33'$

$$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 320\left(\frac{0.6(102)}{33}\right)^{1/3} = 393.15$$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{147+102}{393.15}\right)^{0.63}}} = 0.824 \text{ (N-S)}$$

E-W Direction ⇒ $B = 94.33'$
$h = 102$
$L_{\bar{z}} = 393.15$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{94.33+102}{393.15}\right)^{0.63}}} = 0.843 \text{ (E-W)}$$

N-S Direction ⇒ $$G = 0.925\left(\frac{(1+1.7(3.4)(0.280)(0.824))}{1+1.7(3.4)(0.280)}\right) = 0.824 \text{ (N-S)}$$

E-W Direction ⇒ $$G = 0.925\left(\frac{(1+1.7(3.4)(0.280)(0.843))}{1+1.7(3.4)(0.280)}\right) = 0.835 \text{ (E-W)}$$

E. Enclosure Classification (6.5.9)

⇒ Enclosed (6.2)

F. Internal Pressure Coefficients (Fig 6-5)

⇒ $GC_{pi} = \pm 0.18$

5 Determine velocity Pressure exposure coefficient K_z or K_h (Table 6-3)

$Z_g = 1200 \quad \alpha = 7.0$

$K_z(18') = 2.01\,(18/1200)^{2/7} = 0.61$

$K_z(36') = 2.01\,(36/1200)^{2/7} = 0.74$

$K_z(52') = 2.01\,(52/1200)^{2/7} = 0.82$

$K_z(68') = 2.01\,(68/1200)^{2/7} = 0.89$

$K_z(84') = 2.01\,(84/1200)^{2/7} = 0.94$

$K_z(102') = 2.01\,(102/1200)^{2/7} = 0.99$

* using same K_z for both directions to be conservative

6 Determine Velocity Pressure (6.5.10)

$q_z = 0.00256\,K_z K_{zt} K_d V^2 I$

$K_{zt} = 1.0$
$K_d = 0.85$
$V^2 = 8100$
$I = 1.15$

$q_z = 0.00256\,K_z(0.85)(8100)(1.15) = 20.27\,K_z$

$q_z(18) = 12.36$
$q_z(36) = 15.00$
$q_z(52) = 16.62$
$q_z(68) = 18.04$
$q_z(84) = 19.05$
$q_z(102) = 20.07$

7. Determine External Pressure Coefficient, C_p (Fig 6-6 to 6-8)

$C_{p,w} = 0.8$

Wind in N-S Direction

$\frac{L}{B} = \frac{94.67'}{147'} = 0.64$

$C_{p,L} = -0.5$

Wind in E-W Direction

$\frac{L}{B} = \frac{147}{94.67} = 1.56$

$C_{p,L} \Rightarrow \frac{2-1}{-0.3+0.5} = \frac{2-1.56}{-0.3-x} \Rightarrow x = -0.388$

8. Roof Pressure Coefficients

$\theta = \tan^{-1}(5/12) = 26.1° > 10°$

Wind in N-S Direction (windward)

$h/L = 110.5/94.67' = 1.17 \geq 1.0$

Interpolate ⇒

25	26.1	30
-0.5	x	-0.3
0	y	0.2

x = -0.456
y = 0.044

$C_{p,w} = -0.456, 0.044$

Wind in N-S Direction (Leeward)

$\theta = 26.1 > 20°$

$C_{p,L} = -0.6$

* For mansard roofs, the top horizontal surface and leeward inclined surface shall be treated as leeward surfaces from table (Table 6-6 Note 8)

<u>Wind in E-W Direction</u> (windward)

$h/L = 110.5/147 = 0.75 \Rightarrow 0.5 < 0.75 < 1.0$

interpolate ⇒

	25	26.1	30
0.5	-0.3	-0.278	-0.2
0.75		-0.367	
1.0	-0.5	-0.456	-0.3

	25	26.1	30
0.5	0.2	0.2	0.2
0.75		0.122	
1.0	0	0.044	0.2

$C_{p,w} = -0.367, 0.122$

<u>Wind in E-W Direction (leeward)</u>

$\theta = 26.1 > 20$

$C_{p,l} = -0.6$

<u>Summary of Cp values</u>

		Walls	Roof
NS Direction	windward	0.8	-0.456, 0.044
	leeward	-0.5	-0.6
EW Direction	windward	0.8	-0.367, 0.122
	leeward	-0.388	-0.6

8. Calculate Wind Pressure P on each surface

Wind Pressure for Walls

⇒ See excel sheet for pressures.

8. Calulate Wind Pressure, P, on each surface

Equation: $p=qGC_{pi}$

Constants:

G(NS) = 0.824

G(EW)= 0.835

q_h= 20.6

Building Width NS= 147'

Building Width EW= 94.33'

Wind Pressures (N-S Direction)					
Floor Height	q_z	Windward Pressure (PSF)	Leeward Pressure (PSF)	Trib Area (SF)	Force (K)
18	12.36	8.15	-8.49	2646	44
36	15	9.89	-8.49	2499	46
52	16.62	10.96	-8.49	2352	46
68	18.04	11.89	-8.49	2352	48
84	19.05	12.56	-8.49	2499	53
102	20.07	13.23	-8.49	1323	29
				Base Shear=	265

Wind Pressures (E-W Direction)					
Floor Height	q_z	Windward Pressure (PSF)	Leeward Pressure (PSF)	Trib Area (SF)	Force (K)
18	12.36	8.26	-6.67	1698	25
36	15.00	10.02	-6.67	1604	27
52	16.62	11.10	-6.67	1509	27
68	18.04	12.05	-6.67	1509	28
84	19.05	12.73	-6.67	1604	31
102	20.07	13.41	-6.67	849	17
				Base Shear=	155

Wind Pressure for Roof

$p = q_h G C_p$

$q_h = q_z(110.5) = 0.00256\left[2.01\left(\frac{110.5}{1200}\right)^{2/7}\right](0.85)(8100)(1.15)$

$= 20.6$

N-S Direction - windward

$p = (20.6)(0.824)(-0.456) = -7.74$ psf

$p = (20.6)(0.824)(0.044) = 0.75$ psf

N-S Direction - leeward

$p = (20.6)(0.824)(-0.6) = -10.18$ psf

E-W Direction - windward

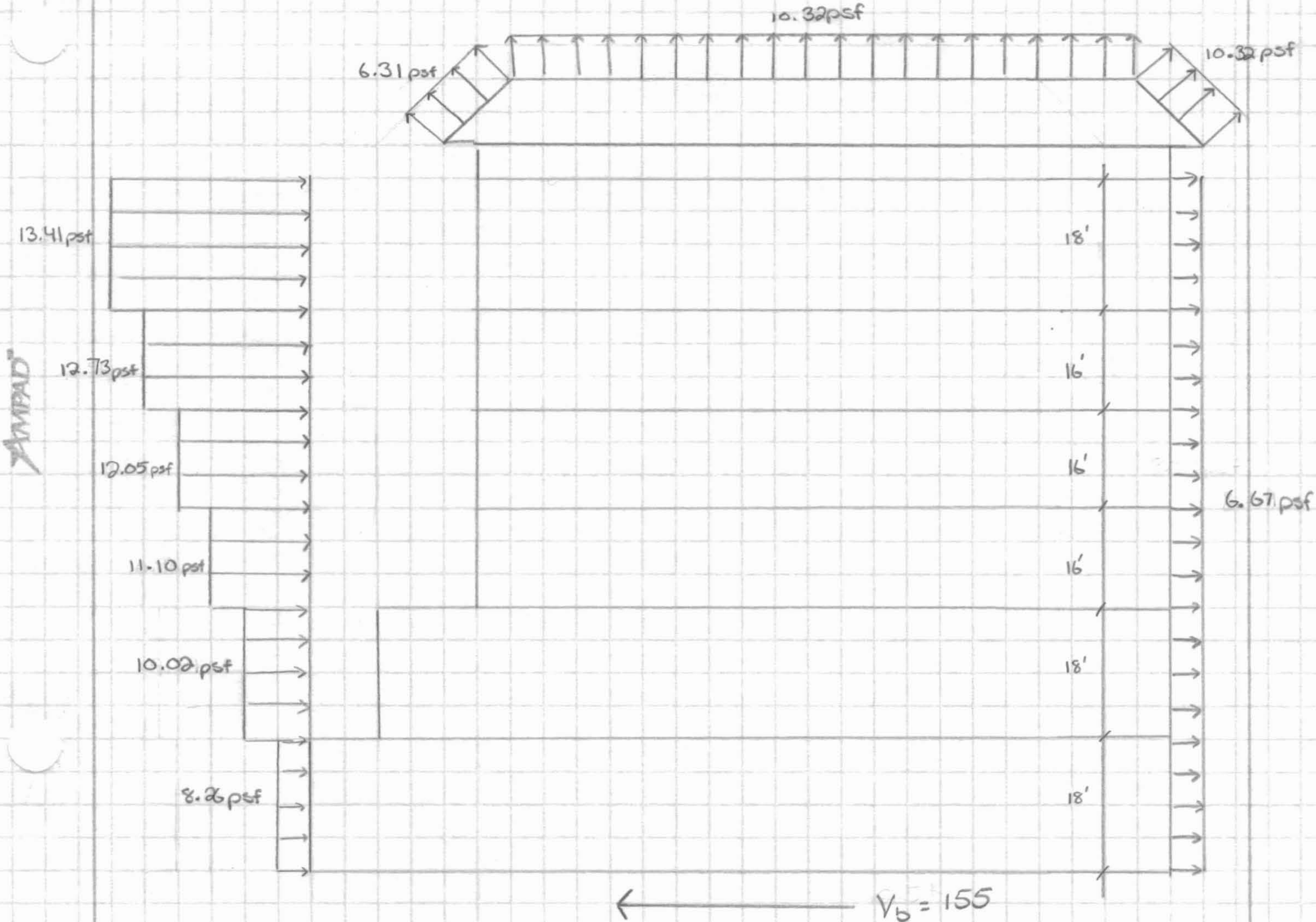
$p = (20.6)(0.835)(-0.367) = -6.31$ psf

$p = (20.6)(0.835)(0.122) = 2.10$ psf

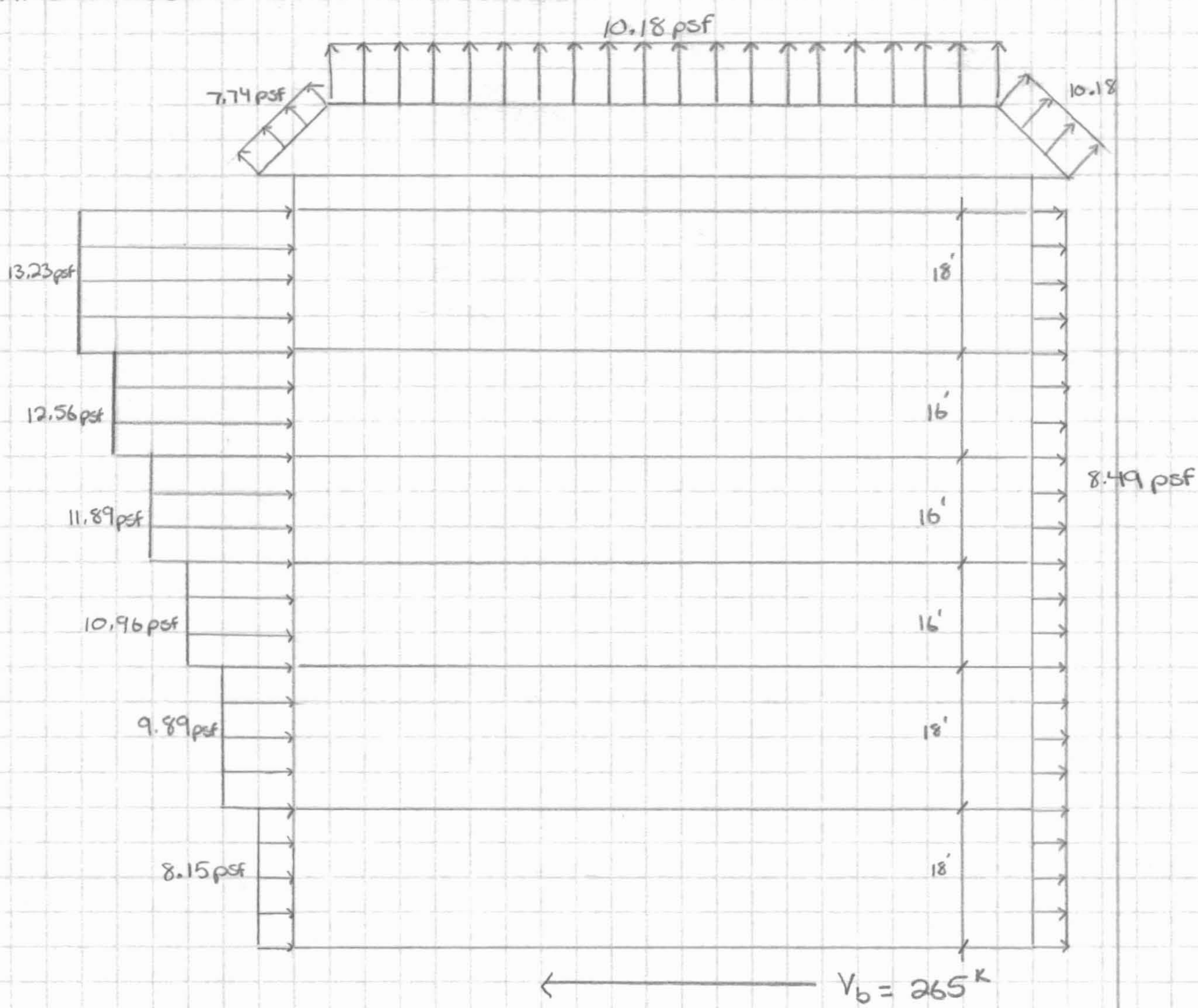
E-W Direction - leeward

$p = (20.6)(0.835)(-0.6) = -10.32$ psf

Wind Pressure Diagram - EW Direction



Wind Pressure - NS Direction



Seismic Load Calculation

1.) Exemptions (11.1.2)

⇒ Building is not exempt

2.) Design Spectral Responce Acceleration (11.4)

A. Site Class (11.4.2)

⇒ B

B. Acceleration Parameters (11.4.3 + Chp 22)

$S_S = 0.332g$
$S_1 = 0.094g$

C. Check to see if adjust for site class (11.4.2 + 11.4.3)

$S_S > 0.15$ + $S_1 > 0.04$ ⇒ Adjust for site class

$S_{MS} = F_a S_S = (1.0)(0.332g) = 0.332g$
$S_{M1} = F_v S_1 = (1.0)(0.094g) = 0.094g$

D. Determine Spectral Acceleration Parameters (11.4.4)

$S_{DS} = 2/3\, S_{MS} = 2/3(0.332g) = 0.221g$
$S_{D1} = 2/3\, S_{M1} = 2/3(0.094g) = 0.063g$

* cant use simplified b/c building doesnt meet requirements (12.14)

3) Seismic Design Catagory (11.6)

Occupancy Catagory III
$0.167 < S_{DS} < 0.33$ ⇒ B

4) Analysis Procedure Selection (Table 12.6-1)

⇒ Equivalent Lateral Force Analysis

5) Determine R (Table 12.2-1)

⇒ ordinary reinforced concrete shear walls ⇒ $R = 4$

6) Importance Factor (Table 11.5-1)

⇒ Occupancy Catagory III ⇒ $I = 1.25$

7) Find Period T (12.8.2.1)

$T_a = C_t h_n^x$

$h_n = 119$ ft
$C_t = 0.02$
$x = 0.75$

$T_a = (0.02)(119)^{0.75} = 0.721$

8) Determine TL (Fig 22-12 to 22-16)

$T_L = 12$ sec

9) Determine Seismic Responce Coefficient Cs (12.8.1.1)

$C_s = \frac{S_{DS}}{(R/I)} = \frac{0.221}{(4/1.25)} = 0.0691$

Check: $T_a = 0.721 < T_L = 6$

$C_s = \frac{S_{D1}}{T(R/I)} = \frac{0.063}{(.721)(4/1.25)} = 0.0273$

$C_s = \begin{cases} 0.0691 \\ \min\ 0.0273 \end{cases} \Rightarrow 0.0273 > 0.01$ ✓

$C_s = 0.0273$

10) Calculate Seismic Weight W

Roof

Typical Roof Bay Dead Load = 117 psf × 9905 sf × 1/1000
= 1158.9^k

Distributed Line Load = 133.1 plf × 357 ft × 1/1000
= 47.5^k

Total Roof weight = 1206.4^k

Floor

Typical Floor Dead Loads = 105.5 psf
Partitions = 27 psf

Total Floor Dead Loads :

Level 2 = 132.5 × 12,859 /1000 = 1703.8^k
Level 3 = 132.5 × 12,513 /1000 = 1658.0^k
Level 4 = 132.5 × 11,115 /1000 = 1472.7^k
Level 5 = 132.5 × 10,379 /1000 = 1375.2^k
Level 6 = 132.5 × 10,258 /1000 = 1359.2^k

Total Weight = 8775.3^k

11) Calculate Base Shear V (12.8.1)

$V = C_s W$

$= (0.0273)(8775.3^k)$

$= 239.57^k$

12) Vertical Distribution of Forces (12.8.3)

$$F_x = C_{vx} V = \left[\frac{w_x h_x^k}{\sum w_x h_x^k} \right] V$$

k: $T_a = 0.721 \Rightarrow 0.5 < 0.721 < 2.5$

$$\frac{2.5 - 0.5}{2 - 1} = \frac{2.5 - 0.721}{2 - k} \Rightarrow k = 1.11$$

⇒ See excel table table on next page

12. Vertical Distribution of Forces

k= 1.11

Vb= 239.57 K

Calculation of Story Forces					
Level	w_i (K)	h_i (FT)	$w_i h_i^k$ (K-FT)	C_{vx}	F (K)
Roof	1206.4	102	446685.20	0.256	61.27
6	1359.2	84	411049.90	0.235	56.38
5	1375.2	68	329360.11	0.189	45.18
4	1472.7	52	263858.18	0.151	36.19
3	1658.0	36	200094.25	0.115	27.45
2	1703.8	18	95549.22	0.055	13.11
		Sum=	1746596.86	1.000	239.57

Story Forces Diagram