Letter of Transmittal

October 3, 2013

Heather Sustersic
Structural Thesis Advisor
The Pennsylvania State University
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Dear Professor Sustersic,

This report was written to fulfill the second of five technical report requirements set by the structural faculty for Penn State's Senior Thesis Capstone Project. This report, Technical Report 2, was assigned September 13, 2013.

The purpose of Technical Report 2 is to define and determine the structural design loads of the RGA Global Headquarters including identifying building codes, specifications and other documents relevant to the design. The scope of this report includes gravity, snow, wind, and seismic load determination limited to the main lateral force resisting system only. Lateral load distribution to elements in the system will be explored in a future technical report.

Thank you in advance for reviewing this report and the following consultation. I look forward to hearing your feedback.

Sincerely,

Natasha Beck
Structural Option
Architectural Engineering Thesis Student

Enclosed: Technical Report 2

Reinsurance Group of America (RGA) Global Headquarters

Technical Report 2

Building Codes, Specifications, and Loads

16600 Swingley Ridge Rd.
Chesterfield, MO

Natasha Beck, Structural
Heather Sustersic
30 September 2013

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General Information

This section provides background information for RGA Global Headquarters.

Reinsurance Group of America (RGA) Global Headquarters

16600 Swingley Ridge Rd. Chesterfield, MO

Natasha Beck | Structural

http://www.engr.psu.edu/ae/thesis/portfolios/2014/nmb5163/index.html

Project Team

Owner: Reinsurance Group of America, Inc.
Owner Representative: Gateway Ridge LLC
General Contractor: Clayco
Architect: Gensler
Structural Engineer: Uzun & Case
Civil Engineer: Stock & Associates, Inc.
Landscape Architect: Forum Studio
Lighting Consultant: Randy Burkett Lighting Design, Inc.
MEP & Fire Protection Engineer: Environmental Systems Design, Inc.

Architecture

- Two skewed, 5 story office towers with curtain wall façades are linked by an amenities level
- Open plan office towers with a central core maximizing circulation, flexibility and daylight
- Amenities include kitchen and seating, fitness center, café and landscaped terrace
- Two story underground parking garage with limestone façade where it is exposed
- Three bro-retention basins are a focal point of the surrounding landscape
- Designed to achieve LEED Silver

Structural

- Two, 5 story steel office towers with composite concrete floors having 3 1/2" semi-lightweight concrete topping
- Upper four levels cantilever 40' over the first level and is supported by a steel truss and plate girder system
- Office towers have a braced frame lateral system while the parking garage utilizes reinforced concrete shear walls
- Two story post-tensioned, reinforced concrete underground parking garage
- Drilled concrete piers 36" to 78" in diameter with an allowable end bearing pressure of 80 ksf

Building Information

Occupancy: General office and training use for a Fortune 500 company
Size: 405,000 square feet
Total Estimated Cost: $150 million
Project Delivery: Design-Build
Construction Period: March 2013 to September 2014

Mechanical

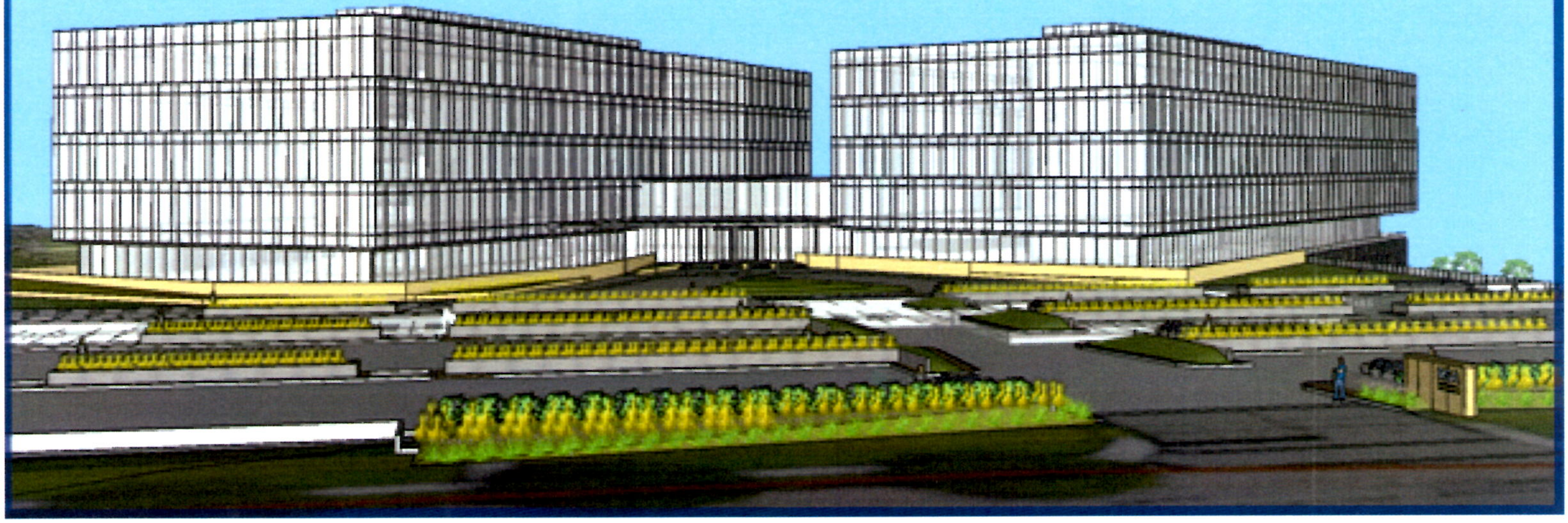
- Designed for year-round cooling
- Three, 350 ton water cooled chillers are serviced by cooling towers
- Four 60,000 CFM mechanical penthouse air handling units serve the office towers
- A medium pressure loop is provided on each floor for VAV branches as needed for flexibility
- Separate fan powered terminal units (FPTU) heat the floor cavity of the cantilever space to counteract a potential heat sink

Lighting & Controls

- Occupancy sensors in restrooms
- Exterior and restroom lighting fixtures on 277 volts
- Fluorescent lamps and LED lamps specified to date
- Magnetic and electronic ballasts with fluorescents and drivers with LEDs
- Remainder of interior lighting design fit-out is currently in the final stages of design

Electrical

- Mechanical equipment and lighting serviced by a 480/277 volt system and office receptacles are serviced by208/120 volt system
- Both systems are fed by 3-phase, 4-wire buses
- Four main switchboards (MSWBD) are rated at 3000 amperes
- Panelboards are rated for 100, 225, 400, 600, or 800 amperes
- Emergency and standby equipment is supported by a diesel engine



Executive Summary

The purpose of this technical report is to evaluate the existing structural systems in the Reinsurance Group of America's Global Headquarters. This included preliminary analysis of the gravity and lateral systems and any unique structural features of the project. It looks at the main structural components and their influence on the load paths for wind, seismic, soil and gravity, which influence the main structural systems.

This preliminary research was executed by reviewing project documents, primarily drawings, and tracking these systems throughout the buildings. Findings of the systems' functionality and influence on other pieces of the project were then recorded and supporting information compiled into the body of this report.

In conclusion, critical structural features that will influence future analysis are the 40' cantilever truss system and maintaining the integrity of the soil load path so that it does not redistribute into the post-tensioned slabs.

Site Plan

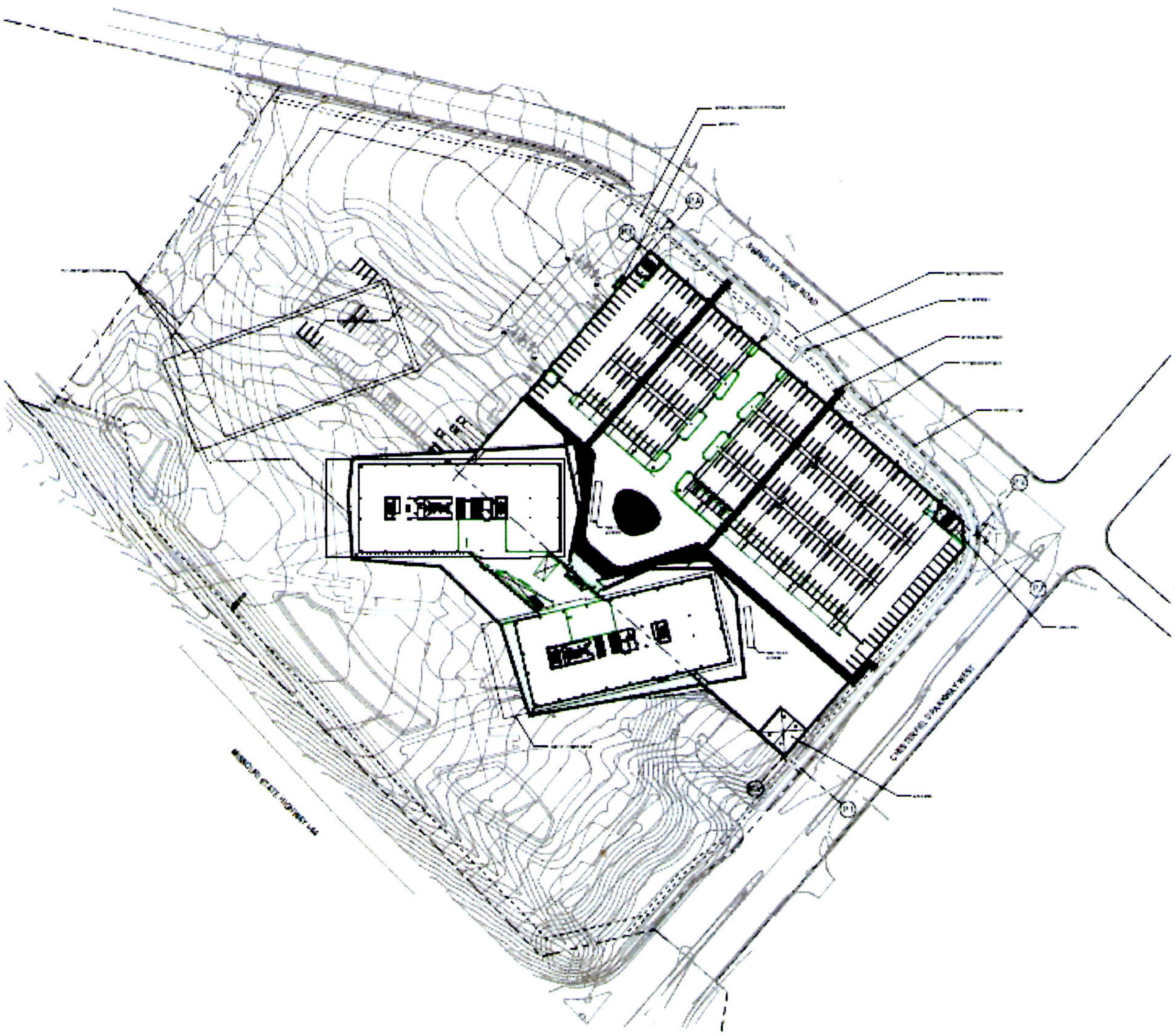
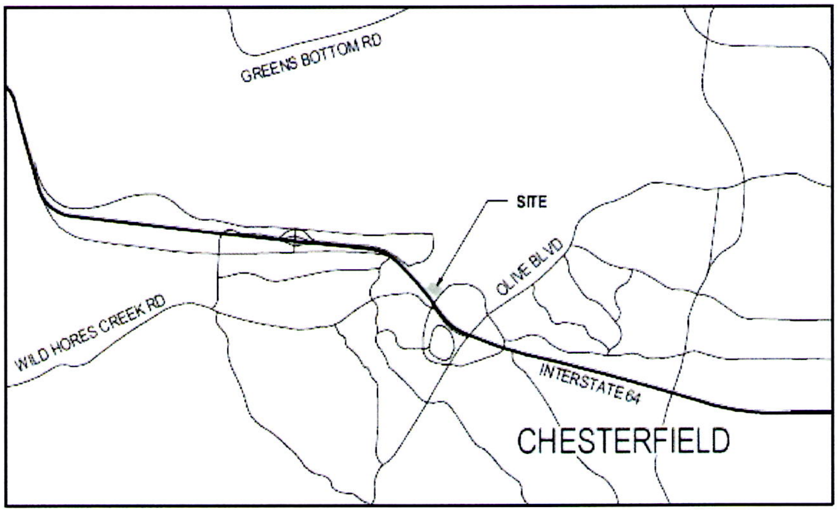


Figure 1: RGA Global Headquarters Site Plan by Gensler

Vicinity and Location Plans

VICINITY MAP



LOCATION PLAN

Figure 2: Vicinity and Location Plans by Gensler

Documents List

Listed below are the documents used in preparation of Technical Report 2.

- *RGA Core and Shell Addendum A* Design Documents by the Project Team (See Abstract)
- Minimum Design Loads for Buildings and Other Structures, ASCE 7-05
- AISC Steel Construction Manual, AISC 360-10
- Vulcraft Composite Deck Tables
- Vulcraft Steel Roof and Floor Deck Tables
- Specification Section 07 54 00-Elastomeric Single Ply Membrane Roofing (TPO)
- Specification Section 08 80 00-Glass and Glazing
- Indeterminate Structures Class Notes

Gravity Loads

This section presents gravity load determination.

LOAD SUMMARY TABLE

OCCUPANCY	DEAD (PSF)	NOTES	LIVE (PSF)	NOTES
OFFICE FLRS	20	NOTE 1	50	ASCE TABLE 4-1
ASSEMBLY AREAS	10	FIRM STD.	100	LOBBIES TBL 4-1
STAIRS	10	FIRM STD.	100	TBL 4-1
ROOFS	25	NOTE 3	20	ORDINARY FLAT ROOF, 4-1
OFFICE LOBBY	40	NOTE 4	100	TBL 4-1
PARKING GARAGE	5	FIRM STD.	40	PASSENGER VEHICLES, 4-1
TOP PARKING LVL	5	FIRM STD.	100	TBL 4-1
BALCONIES	50	NOTE 2	100	EXTERIOR, TBL 4-1
STORAGE RMS	10	FIRM STD.	125	LT STORAGE, TBL 4-1
MECHANICAL RMS	10	FIRM STD.	125	LT. MANUFACTURING, 4-1
ELEVATOR MACHINE	10	FIRM STD.	150	LOCATED IN PENTHOUSE, ELEVATOR EQUIPMENT TYP. HEAVIER THAN AHU'S

- LOADS SUMMARIZED FROM S0.001

NOTE 1: OFFICE FLOOR DEAD LOAD ASSUMES 15 PSF PARTITION LOAD.

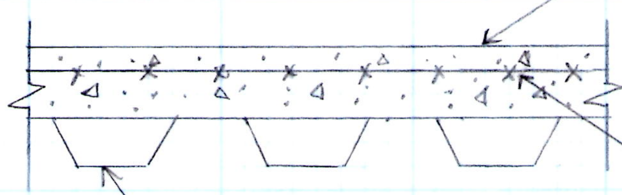
NOTE 2: BALCONIES HAVE GRANITE PEDESTRIAN PAVERS (2")
FROM AISC 360-10 TABLE 17-12: GRANITE 156-193 PCF
OR 26 - 32 PSF

NOTE 3: ROOFS HAVE TPO SINGLE PLY WITH CONCRETE PAVERS

NOTE 4: INTERIOR LOBBY FLOOR FINISH 3" TERRAZZO FINISH.
FROM TABLE 17-12: 1" TERRAZZO = 13 PSF ∴ 3"
TERRAZZO = 39 PSF.

TYPICAL FLOOR BAY LOADING

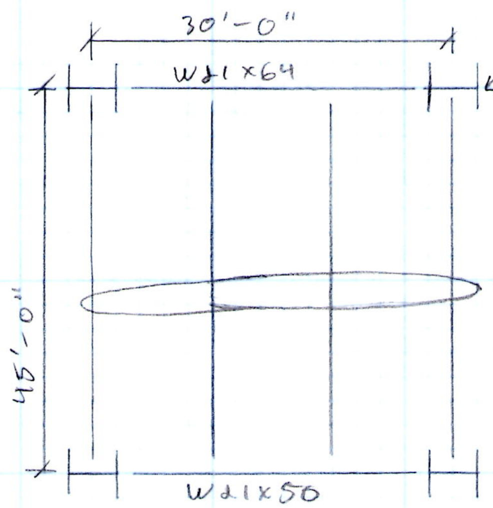
DEAD LOAD



116 PCF ($^{3.5''}/_{12}$) = 33.8 PSF
WWF: 0.42 PSF
DECK: 2.14 PSF

36.4 PSF FLOOR SYSTEM

TYPICAL BAY:



14'-0" FLR-TO-FLR HT

64(30') + 50(30') = 3420#
87(4)(14') = 4872#
44(4)(45') = 7920#

16212# / (30'x45') = **12 PSF** STEEL FRAMING

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PROJECT	RGA GLOBAL HQ TECHNICAL REPORT 2
TITLE	GRAVITY LOADS FLOOR LOADS
BY:	NMB
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• TOTAL DEAD LOAD:

FLOOR SYSTEM: 36 PSF
STL FRAMING: 12 PSF
SUPERIMPOSED DL: 20 PSF (FROM S0.001, ASSUMING INCLUDES 5 PSF M/E/P AND LISTED 15 PSF PARTITIONS)

68 PSF TYP. FLOOR DEAD LOAD

LIVE LOAD

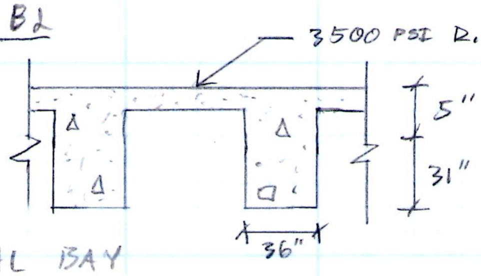
• DESIGN LIVE LOAD MINIMUM

LL = 50 PSF [ASCE 7-05 TABLE 4-1]

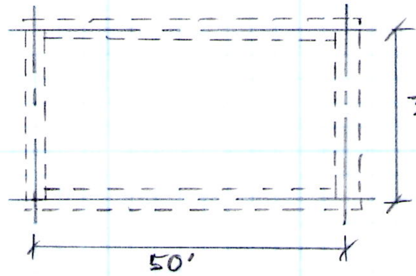
• ON SHEET S0.001, THE SUPERIMPOSED DESIGN LIVE LOAD IS 50 PSF WHICH IS EQUAL TO THE CODE MINIMUM IN ASCE 7-05.

TYPICAL PARKING GARAGE FLOOR LOADING

DEAD LOAD B2



• TYPICAL BAY



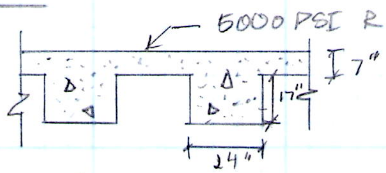
SLAB: 150 PCF (5"/12) = 62.5 PSF

BEAMS: 150 PCF (31/12)(36/12)(2·50' + 2·30')(1/50'·30') = 124 PSF

DL_{B2} = 62.5 PSF + 124 PSF + 5 PSF (SDL) => **DL_{B2} = 192 PSF**

LL = 40 PSF

DEAD LOAD B1



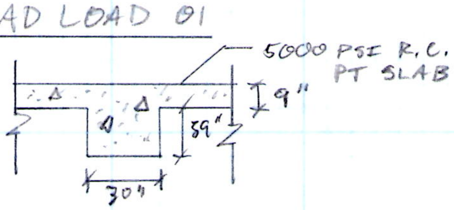
SLAB: 150 PCF (7"/12) = 87.5 PSF

BEAMS: 150 PCF (24/12)(17/12)(160')(1/1500 SF) = 45 PSF

COLUMNS: 150 PCF (24/12)(24/12)(11.17')(1/1500 SF) = 4.46 PSF

DL_{B1} = 87.5 PSF + 45 PSF + 4.46 PSF + 5 PSF (SDL) => **DL_{B1} = 142 PSF**

DEAD LOAD 01



SLAB: 150 PCF (9"/12) = 112 PSF

BEAMS: 150 PCF (30/12)(39/12)(160/1500) = 130 PSF

COLUMNS: 150 PCF (2')(2')(14.83)(1/1500 SF) = 5.93 PSF

DL_{01} = 112 + 130 + 5.93 + 5 (SDL)

DL_{01} = 253 PSF

AVG SLAB THICK.: (8.5" + 9.5")/2 = 9"

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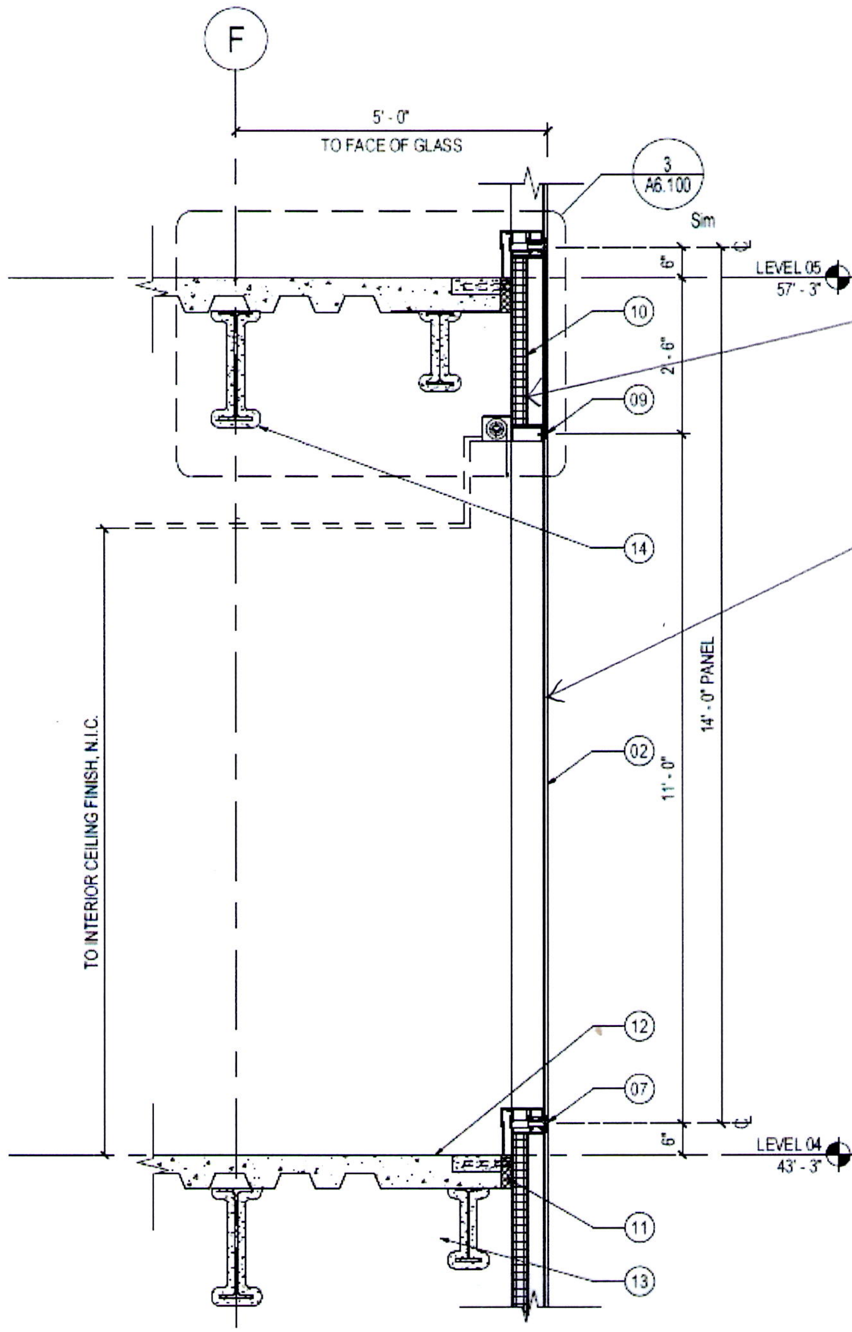
TYPICAL EXTERIOR WALL SECTION

(DETAIL NEXT PAGE)



INSULATED SHADOW BOX: 4" RIGID INSULATION

"EGL-1" UNIT:

- 5/8" THICK LOW IRON GLASS
- 5/8" ARGON FILLED AIRSPACE
- (2) 3/16" THICK LOW IRON GLASS WITH PVB INTERLAYER

[FROM 14/A4.120]

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TITLE: GRAVITY LOADS EXT. WALL LOADS

BY: NMB

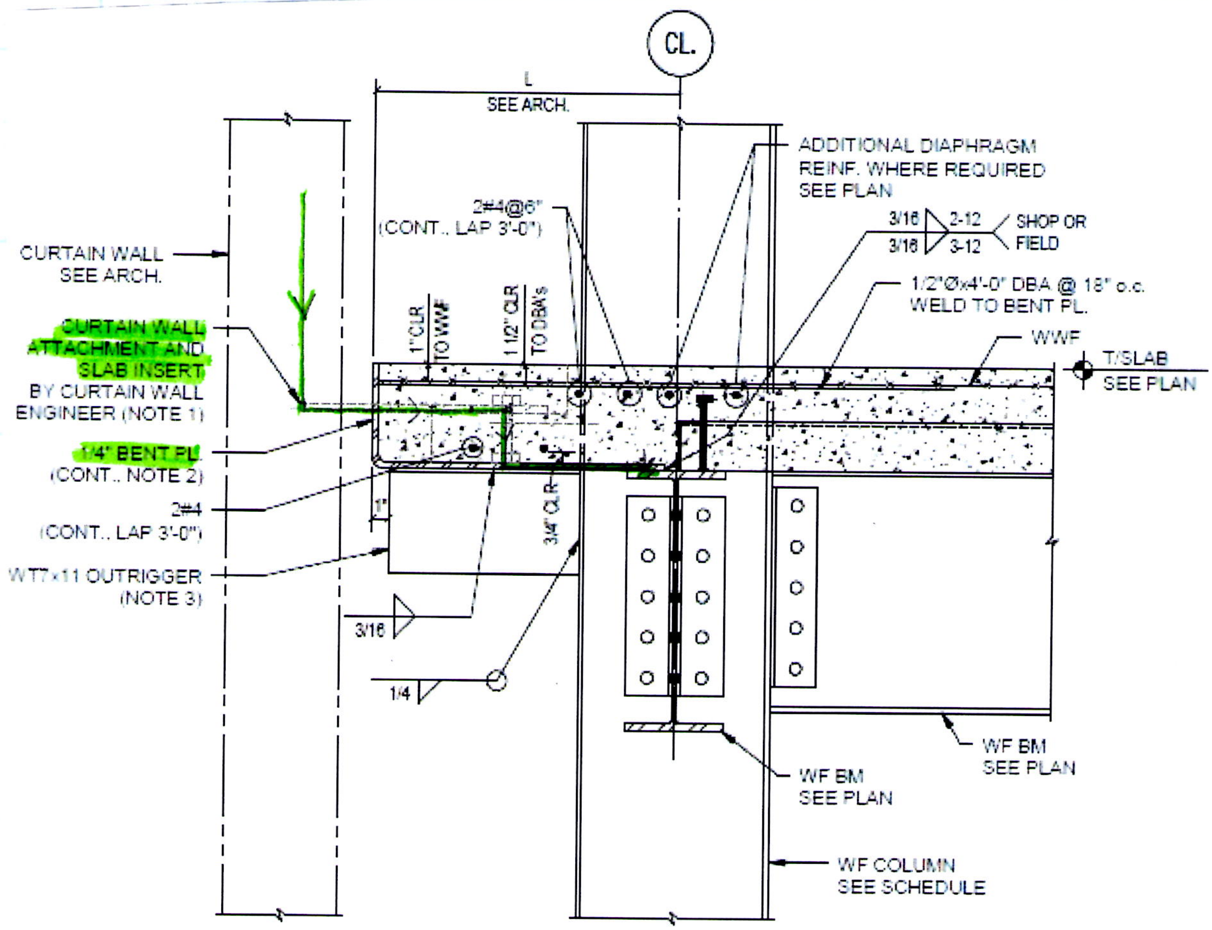
SHEET: 6

CHKD:

PROJECT NO: TECH2

DATE:

TYPICAL C.W. ATTACHMENT DETAIL



[FROM 14/S0.004]

LOAD PATH DESCRIPTION

- THE CURTAIN WALL IS ATTACHED TO THE SLAB INSERT. THIS TRANSFERS THE LOAD INTO THE METAL STUD IN THE SLAB.
- THE METAL STUD TAKES THE LOAD THROUGH A WELD INTO THE 1/4" BENT PLATE.
- THE LOAD TRAVELS THROUGH THE BENT PLATE, CONTINUOUS INTO AND OUT OF THE PAGE, ONTO THE GIRDER BY A WELD.
- THE RESULTING DEAD LOAD IS A LINE LOAD ON THE PERIMETER BEAMS.

CURTAIN WALL DEAD LOAD

• USING MINIMUM DESIGN LOADS FROM ASCE 7-05 TABLE C3-1:

RIGID INSULATION (½") ⇒ 0.75 PSF

DL = (0.75 PSF)(8)(3'-0") = **18 PLF**
4"/½" ↑

TABLE C3-2:

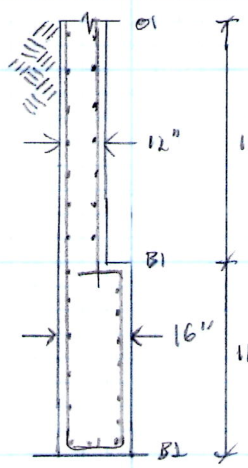
GLASS ⇒ 160 PCF

DL = (160 PCF)(1/12)(5/8" + 2 · 3/16")(14'-0") = **187 PLF**

(187 PLF + 18 PLF)(1.1) = 226 PLF
CONNECTIONS ALLOWANCE ↑

C.W. DEAD LOAD = 226 PLF

PARKING GARAGE WALL DEAD LOAD



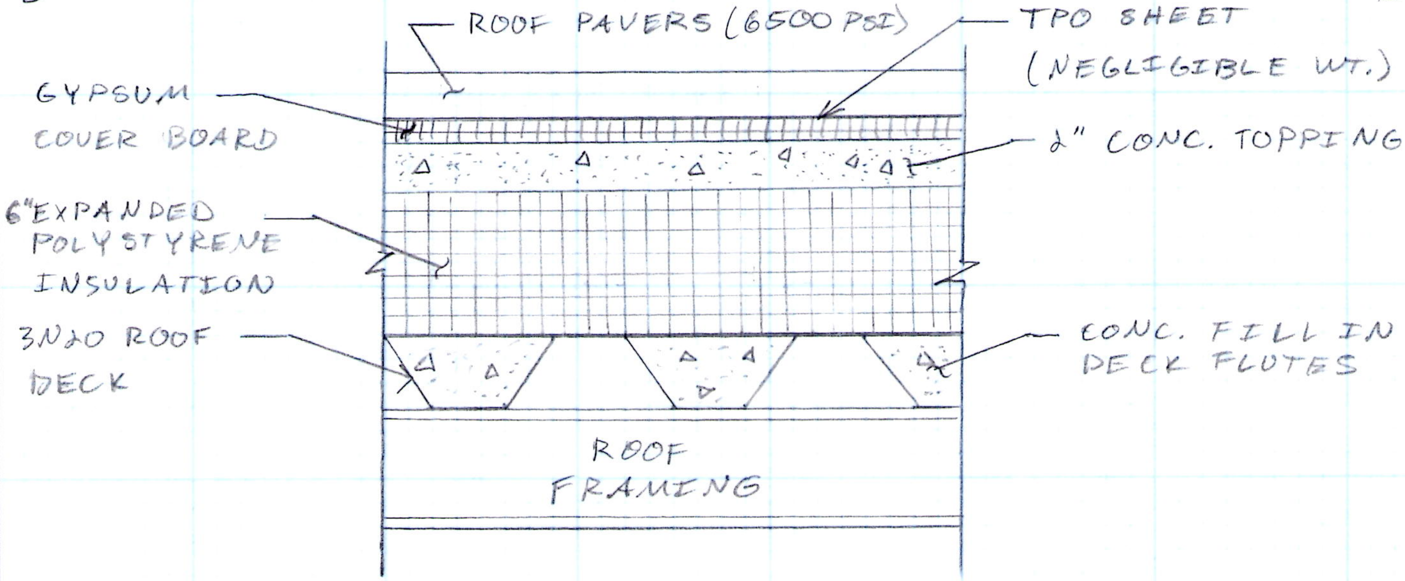
150 PCF(14/12)(14.83') = **2220 PLF**

150 PCF(16/12)(11.17') = **2234 PLF**

TYPICAL ROOF BAY LOADING

DEAD LOAD

[FROM SPECIFICATION 07 54 00 - ELASTOMERIC SINGLE PLY MEMBRANE ROOFING (TPO)]



ROOF PAVERS: = 22 PSF

GYPSUM BOARD: (½")/12 (50 PCF) = 2.1 PSF

ASCE 7-05 TABLE C3-2 ↑

CONC. TOPPING: (2"/12)(116 PCF) = 19 PSF

FROM S1.206.A1 ↑

POLYSTYRENE: (6"/12)(1 PCF) = 0.5 PSF

CONC. FILL: (½(3")/12)(116 PCF) = 14.5 PSF

AVG. FILL AND VOIDS ↑

3N20 METAL DECK (VULCRAFT) = 2.71 PSF

STL FRAMING (SAME AS FLOOR) = 12 PSF

73 PSF MAT'L DEAD LOAD

SUPERIMPOSED DEAD LOAD = 25 PSF

FROM S0.001 ↑

98 PSF ROOF DEAD LOAD

LIVE LOAD

- CODE MINIMUM FROM ASCE 7-05 FOR ORDINARY FLAT ROOFS: **L_r = 20 PSF**
- FROM S0.001, DESIGN LOAD MATCHES CODE MINIMUM.

SNOW LOAD

[FROM ASCE 7-05]

GROUND SNOW LOAD

- FROM SNOW LOAD MAPS, FIG. 7-1: **$P_g = 20$ PSF**
- FROM SHEET S0.001, THE DESIGN LOAD MATCHES THE CODE MINIMUM

FLAT ROOF SNOW LOAD

$P_f = 0.7 C_e C_t I p_g$ [EQN 7-1]

- EXPOSURE FACTOR, C_e
  - NEED TERRAIN CATEGORY FROM §6.5.6:
    HILLY TERRAIN WITH SURROUNDING DEVELOPMENTS AND SOME TREES ∴ EXPOSURE B => TERRAIN B
  - FROM TABLE 7-2: NO OBSTRUCTIONS ∴ FULLY EXPOSED
    ∴ $C_e = 0.9$
- THERMAL FACTOR, C_t
  - STRUCTURE KEPT AT ROOM TEMPERATURE
    ∴ $C_t = 1.0$ [TABLE 7-3]
- SNOW IMPORTANCE FACTOR, I
  - FROM TABLE 1-1: > 300 PPL WILL WORK IN EACH OFFICE STRUCTURE DAILY, ∴ OCCUPANCY III
    ∴ $I = 1.1$ [TABLE 7-4]
- CALCULATE FLAT ROOF LOAD
  $P_f = (0.7)(0.9)(1.0)(1.1)(20 \text{ PSF}) = 14 \text{ PSF} < 20 \text{ PSF}$
  ∴ $P_f = I p_g = (1.1)(20 \text{PSF}) \Rightarrow$ **$P_f = 22$ PSF** [§7.3]
- FROM SHEET S0.001, DESIGN LOAD MATCHES CODE MIN.

DRIFT LOAD

[FROM ASCE 7-05 § 7.7.1]

- CONSIDER DRIFT?

$h_b = p_s / \gamma$ (BALANCED SNOW LOAD)

$\gamma = 0.13 p_g + 14 \leq 30$ PCF (SNOW DENSITY) [EQN 7-3]

$\gamma = 0.13(20) + 14 = 16.6$ PCF < 30 PCF OK

$p_s = C_s p_f$ [§ 7.4.1]

$C_t = 1$ ∴ USE DASHED LINE IN FIG. 7-2a

FLAT ROOF ∴ SLOPE ~0° ∴ $C_s = 1.0$

$p_s = (1.0)(22\text{ PSF}) = 22$ PSF

$h_b = 22/16.6 = 1.33'$

h_c = Penthouse height − h_b

$h_c = 85.25' + 3' - 71.67' - 1.33' = 15.25'$

(3' = PARAPET)

$h_c / h_b = \frac{15.25}{1.33} > 0.2$ ∴ MUST CONSIDER DRIFT

* DRIFT CALCULATION CONT'D NEXT PAGE *

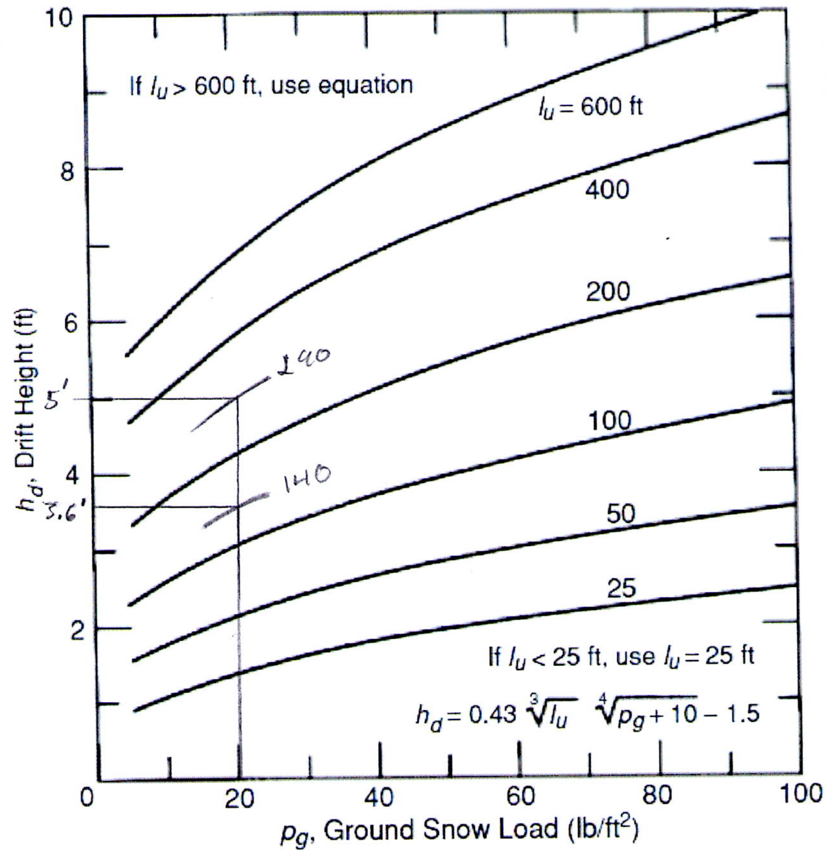
PARTIAL LOADING [§ 7.5]

- NO CONTINUOUS BEAM SYSTEM ∴ NOT APPLICABLE
- OTHERWISE, MEMBER LOAD (OUTSIDE OF SCOPE)

UNBALANCED ROOF SNOW LOADS [§ 7.6]

- FLAT ROOF ∴ NOT APPLICABLE

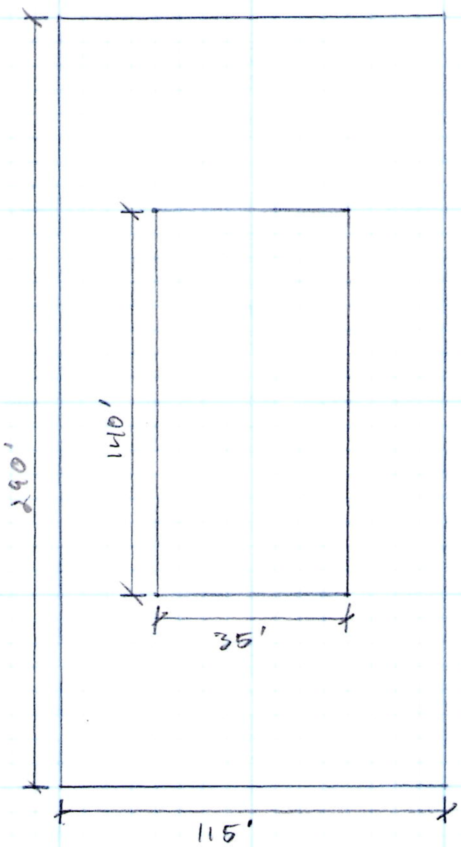
• FROM ASCE 7-05



To convert lb/ft² to kN/m², multiply by 0.0479.
To convert ft to m, multiply by 0.3048.

FIGURE 7-9 GRAPH AND EQUATION FOR DETERMINING DRIFT HEIGHT, h_d

ROOF PLAN



• LEEWARD DRIFT

l_u = LENGTH OF PENTHOUSE = 140'

FROM FIG. 7-9 ABOVE : h_d = 3.6'

• WINDWARD DRIFT

l_u = LENGTH OF TOWER = 240'

FROM FIG. 7-9 : h_d = 5'

$\frac{3}{4}(5') = h_d = 3.75'$ [§ 7.7.1]

$\therefore h_d = 3.75'$

• DRIFT SURCHARGE LOAD

$h_d < h_c \therefore w = 4h_d = 4(3.75') = 15'$, $h_d = 3.75'$

$P_d = h_d \gamma = 3.75'(16.6 \text{ PCF}) =$ **62 PSF SNOW DRIFT LOAD**

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Wind Loads

This section presents wind load determination.

WIND LOADING

ASCE 7-05 ANALYTICAL PROCEDURE

- DETERMINE BASIC WIND SPEED, V
  $V = 90$ mph [FIG. 6-1]

- WIND DIRECTIONALITY FACTOR, K_d
  FOR BUILDINGS, $K_d = 0.85$ [TABLE 6-4]

- IMPORTANCE FACTOR, I
  OCCUPANCY CATEGORY III [TABLE 1-1]
  $I = 1.15$ [TABLE 6-1]

- EXPOSURE CATEGORY
  - HILLY TERRAIN WITH SURROUNDING DEVELOPMENTS AND SOME TREES ∴ EXPOSURE **B** [§ 6.5.6]

- TOPOGRAPHIC FACTOR, K_{zt}
  - BUILDING BUILT INTO LOW HILL NOT ON TOP ∴ $K_{zt} = 1.0$

- GUST FACTOR
  - ESTIMATE NATURAL FREQUENCY
    $n_1 = 75/H$ [EQN. C6-18]
    $H < 300$ ft, $< 4 L_{eff}$ OK
    $n_1 = 75/111.25 = 0.674 < 1$ ∴ **FLEXIBLE**
  - DETERMINE G_f IN NW-SE DIRECTION
    $g_Q = g_v = 3.4$
    $g_r = \sqrt{2\ln(3600 \cdot 0.674)} + \frac{0.577}{\sqrt{2\ln(3600 \cdot 0.674)}} = 4.09$
    - DETERMINE RESPONSE FACTOR, R
      $\bar{b} = 0.45$
      $\bar{\alpha} = 1/4.0 = 0.25$ [TABLE 6-2]
      $\bar{z} = \max \begin{cases} 0.6h = 0.6(104) = 62.4 \\ z_{min} = 30' \end{cases}$

JUSTIFICATION NEXT PAGE ⟶ $h = \frac{97.65' + 111.25'}{2} = 104'$

$\therefore \bar{z} = 62.4'$

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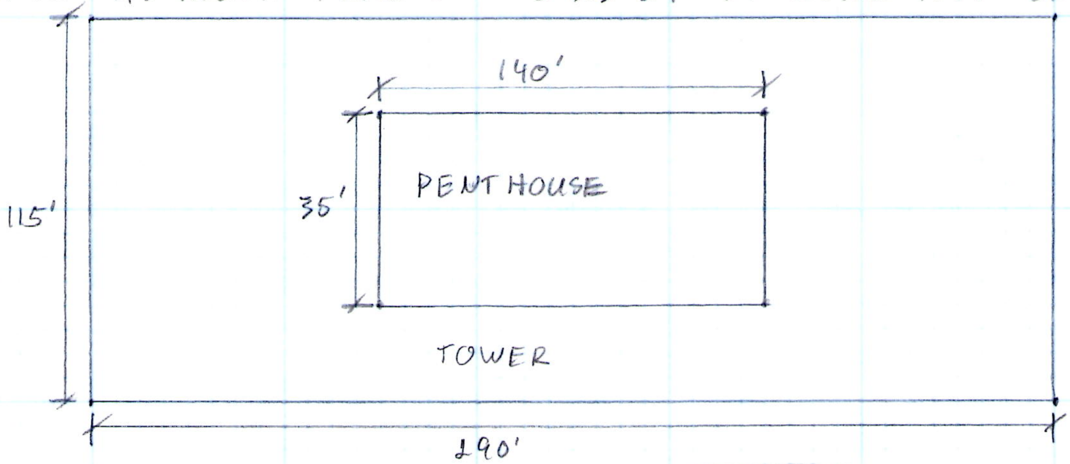
MEAN ROOF HEIGHT JUSTIFICATION

- BECAUSE PENTHOUSE IS SET BACK, IT WILL NOT SEE FULL WIND/ CAUSE AS MUCH TURBULANCE AS IF IT WERE NOT SET BACK.



- AREA RATIO:

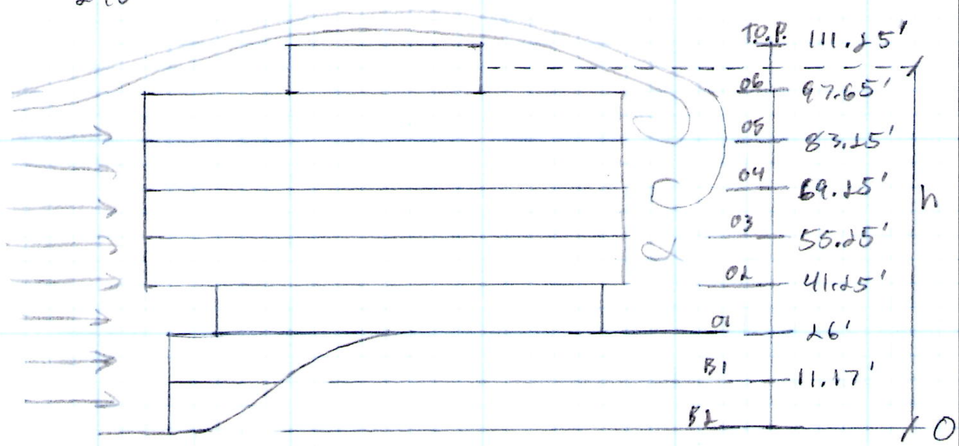
$$\frac{(140)(35)}{(115)(290)} = 0.15 < 0.5$$

- LENGTH RATIO:

$140/290 = 0.48 < 0.5$

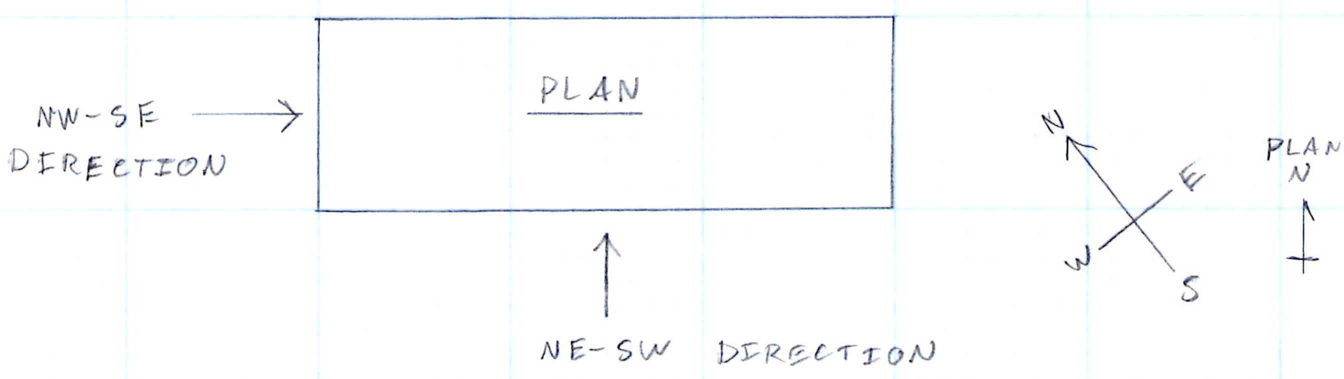
- WIDTH RATIO:

$35/115 = 0.30 < 0.5$



∴ USE MEAN ROOF HEIGHT TO THE MIDHEIGHT OF THE PENTHOUSE.

BUILDING AND WIND DIRECTIONS W.R.T. TRUE NORTH



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$$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V\left(\frac{88}{60}\right) = 0.45\left(\frac{62.4}{33}\right)^{0.25}(90)\left(\frac{88}{60}\right) = 69.7$$

$\ell = 320'$ [TABLE 6-2]

$\bar{\epsilon} = 1/3.0 = 0.33$

$$L_z = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 320\left(\frac{62.4}{33}\right)^{0.33} = 395$$

$$N_1 = \frac{n_1 L_z}{\bar{V}} = \frac{0.674\,(395)}{69.7} = 3.82$$

$$R_n = \frac{7.47 N_1}{(1+10.3N_1)^{5/3}} = \frac{7.47\,(3.82)}{(1+10.3\cdot 3.82)^{5/3}} = 0.060$$

DAMPING RATIO, β FROM COMMENTARY §C6.5.8

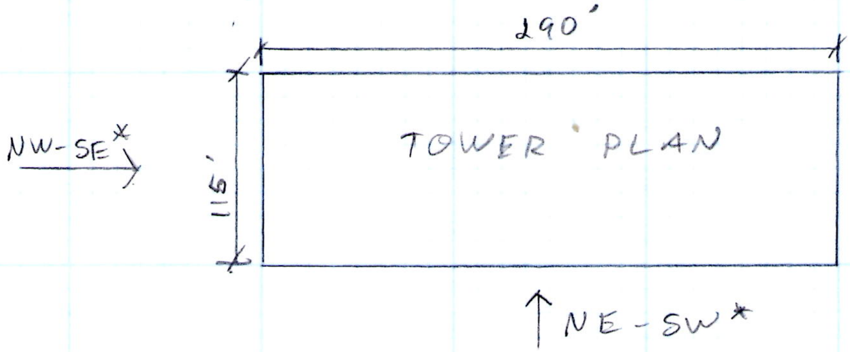
ASSUME $\beta = 0.015$

- FOR R_h

$$n = \frac{4.6 n_1 h}{\bar{V}_z} = \frac{4.6(0.674)(104)}{69.7} = 4.626$$

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

$$= \frac{1}{4.626} - \frac{1}{2\cdot 4.626^2}\left(1 - e^{-2\cdot 4.626}\right) = R_h = 0.192$$



* TRUE NORTH RELATED WIND DIRECTIONS (SEE PREVIOUS PAGE)

	NW-SE	NE-SW
B	115'	290'
L	290'	115'

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PROJECT: RGA GLOBAL HQ TECHNICAL REPORT 2

TITLE: WIND LOAD GUST FACTOR CALCS

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- FOR R_B

$$n = \frac{4.6 n_1 B}{\bar{V}_z} = \frac{4.6(0.672)(115')}{62.7} = 5.670$$

$$R_B = \frac{1}{5.67} - \frac{1}{2 \cdot 5.67^2}\left(1 - e^{-2 \cdot 5.67}\right) = 0.161$$

- FOR R_L

$$n = \frac{15.4 n_1 L}{\bar{V}_z} = \frac{15.4(0.674)(290')}{62.7} = 48.0$$

$$R_L = \frac{1}{48.0} - \frac{1}{2 \cdot 48.0^2}\left(1 - e^{-2 \cdot 48.0}\right) = 0.021$$

$$R = \sqrt{1/\beta \, R_n R_h R_B (0.53 + 0.47 R_L)}$$

$$= \sqrt{(1/0.015)(0.060)(0.192)(0.161)(0.53 + 0.47 \cdot 0.021)}$$

$R = 0.258$

- FIND INTENSITY OF TURBULENCE, I_z

$c = 0.30$ [TABLE 6-2]

$$I_z = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.30\left(\frac{33}{62.4}\right)^{1/6} = 0.270$$

- BACKGROUND RESPONSE, Q

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} = \sqrt{\frac{1}{1 + 0.63\left(\frac{115 + 104}{395}\right)^{0.63}}}$$

$Q = 0.835$

$$G_f = 0.925\left(\frac{1 + 1.7 I_z \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1 + 1.7 g_v I_z}\right)$$

$$= 0.925\left(\frac{1 + 1.7(0.270)\sqrt{3.4^2 \cdot 0.835^2 + 4.09^2 \cdot 0.258^2}}{1 + 1.7(3.4)(0.270)}\right)$$

$G_{f\ NW-SE} = 0.863$

- DETERMINE G_f IN NE-SW DIRECTION

$g_Q = g_v = 3.4$ $\quad \bar{V}_{\bar{z}} = 69.7$ $\quad R_n = 0.060$

$g_r = 4.09$ $\quad L_{\bar{z}} = 395$ $\quad \beta = 0.015$

$\bar{z} = 62.4'$ $\quad N_1 = 3.82$ $\quad I_{\bar{z}} = 0.270$

$R_h = 0.192$ $\quad h = 104'$

- FOR R_B

$$n = \frac{4.6(0.674)(290)}{69.7} = 12.9$$

$$R_B = \frac{1}{12.9} - \frac{1}{2 \cdot 12.9^2}\left(1 - e^{-2 \cdot 12.9}\right) = \mathbf{0.745}$$

- FOR R_L

$$n = \frac{15.4(0.674)(115')}{69.7} = 17.1$$

$$R_L = \frac{1}{17.1} - \frac{1}{2 \cdot 17.1^2}\left(1 - e^{-2 \cdot 17.1}\right) = 0.0568$$

- R

$$R = \sqrt{\left(\tfrac{1}{0.015}\right)(0.060)(0.192)(0.745)(0.53 + 0.47 \cdot 0.0568)} = \mathbf{0.564}$$

- Q

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{290 + 104}{395}\right)^{0.63}}} = \mathbf{0.738}$$

- G_f

$$= 0.925\left(\frac{1 + 1.7(0.270)\sqrt{3.4^2(0.738^2) + (4.09^2)(0.564^2)}}{1 + 1.7(3.4)(0.270)}\right)$$

$\underline{G_{f\,NE-SW} = 1.00}$

- ENCLOSURE CLASSIFICATION [§6.5.9]
  - NO OPENINGS ∴ **ENCLOSED**

- INTERNAL PRESSURE COEFFICIENT, GC_{pi}

$GC_{pi} = \pm 0.18$ [FIG. 6-5]

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• EXTERNAL PRESSURE COEFFICIENTS, C_p

- WALLS NW-SE DIRECTION [FIG. 6-6]

WINDWARD WALL: $C_p = 0.8$ (USE W/ q_z)

SIDE WALL: $C_p = -0.7$ (USE W/ q_h)

LEEWARD WALL:

$L/B = 290/115 = 2.52$

INTERPOLATE:

L/B	C_p
2	-0.3
2.52	-0.274
4	-0.2

$$\frac{(-0.2 - -0.3)}{4-2}(2.52-2) + -0.3 =$$

$C_p = -0.274$ (USE W/ q_h)

- WALLS NE-SW DIRECTION

WINDWARD WALL: $C_p = 0.8$ (USE W/ q_z)

SIDEWALL: $C_p = -0.7$ (USE W/ q_h)

LEEWARD WALL:

$L/B = 115/290 = 0.397 \therefore C_p = -0.5$ (USE W/ q_h)

- ROOF NW-SE DIRECTION

$h/L = 104/290 = 0.36 < 0.5$

HORIZ DIST FROM WINDWARD EDGE	C_p
0 TO 52'	-0.9, -0.18
52' TO 104'	-0.9, -0.18
104' TO 208'	-0.5, -0.18
> 208	-0.3, -0.18

- ROOF NE-SW DIRECTION

$h/L = 104/115' = 0.904$

• 0 TO 52':

0.5	-0.9
0.904	**-1.01**
1.0	-1.3(0.8) = -1.04

$$\frac{-1.04 - -0.9}{1-0.5}(0.904 - 0.5) + -0.9$$

REDUCE? ⇒ (39.25')(290') ~ 11000 ∴ REDUCE BY 0.8

• 52' TO 104'

0.5	-0.9	
0.904	**-0.738**	$\frac{-0.7 - -0.9}{1 - 0.5}(0.904 - 0.5) + -0.9$
1.0	-0.7	

• 104' TO 208'

0.5	-0.5	
0.904	**-0.662**	$\frac{-0.7 - -0.5}{1 - 0.5}(0.904 - 0.5) + -0.5$
1.0	-0.7	

• > 208'

0.5	-0.3	
0.904	**-0.623**	$\frac{-0.7 - -0.3}{1 - 0.5}(0.904 - 0.5) + -0.3$
1.0	-0.7	

* SEE FOLLOWING EXCEL SHEETS FOR PRESSURE CALCULATIONS

• DESIGN WIND PRESSURES

- FOR FLEXIBLE BUILDINGS

$$p = q G_f C_p - q_i (GC_{pi}) \quad \text{[EQN. 6-19]}$$

- FOR PARAPETS

$$P_p = q_p GC_{pn} \quad \text{[EQN. 6-20]}$$

$GC_{pn} = +1.5$ WINDWARD PARAPET
$GC_{pn} = -1.0$ LEEWARD PARAPET

$K_z=2.01(z/z_g)^{2/\alpha}$

$q_z=0.00256K_zK_{zt}K_dV^2I$

Kd=	0.85	
Kzt=	1	
V=	90	mph
I=	1.15	
z_g=	1200	ft

Determine K_z and q_z

Floor	z	z_g (ft)	α	K_z	q_z	OR:
B1	11.17	1200	7	0.528	10.7	
1	26	1200	7	0.673	13.6	
2	41.25	1200	7	0.767	15.6	
3	55.25	1200	7	0.834	16.9	
4	69.25	1200	7	0.890	18.0	
5	83.25	1200	7	0.938	19.0	
6	97.65	1200	7	0.982	19.9	
Tower Parapet	100.65	1200	7	0.990	20.1	q_p
Mean Roof Height	104	1200	7	0.999	20.3	q_h
T.O. Penthouse	111.25	1200	7	1.019	20.7	
Penthouse Parapet	114.25	1200	7	1.027	20.8	q_p

MWFRS ANALYSIS: NE-SW Walls

Floor	z	q	Windward (PSF)	Leeward (PSF)	Tribuary Height(ft.)	Tributary Area(SF)	Story Shear(k)	Story M_{OT}(ft.-k)
B1	11.17	10.7	8.57	-10.1	18.585	5390	100.76	189.2
1	26	13.6	10.91	-10.1	15.04	3685	77.50	1432.3
2	41.25	15.6	12.44	-10.1	14.625	4241	95.73	3248.8
3	55.25	16.9	13.53	-10.1	14	4060	96.04	4633.8
4	69.25	18.0	14.43	-10.1	14	4060	99.70	6206.2
5	83.25	19.0	15.21	-10.1	14.2	4118	104.33	7944.8
6	97.65	19.9	15.92	-10.1	7.2	2088	54.38	5114.5
Tower Parapet	100.65	20.1	30.10	-20.3	3	870	43.81	4344.0
Mean Roof Height	104	20.3	16.21	-10.1	6.975	977	25.71	2584.7
T.O. Penthouse	111.25	20.7	16.52	-10.1	3.625	508	13.52	1480.1
Penthouse Parapet	114.25	20.8	31.21	-20.3	3	420	21.62	2437.3
						Base Shear and M_{OT}=	**733**	**39615**

$p=qG_fC_p-q_i(GC_{pi})$

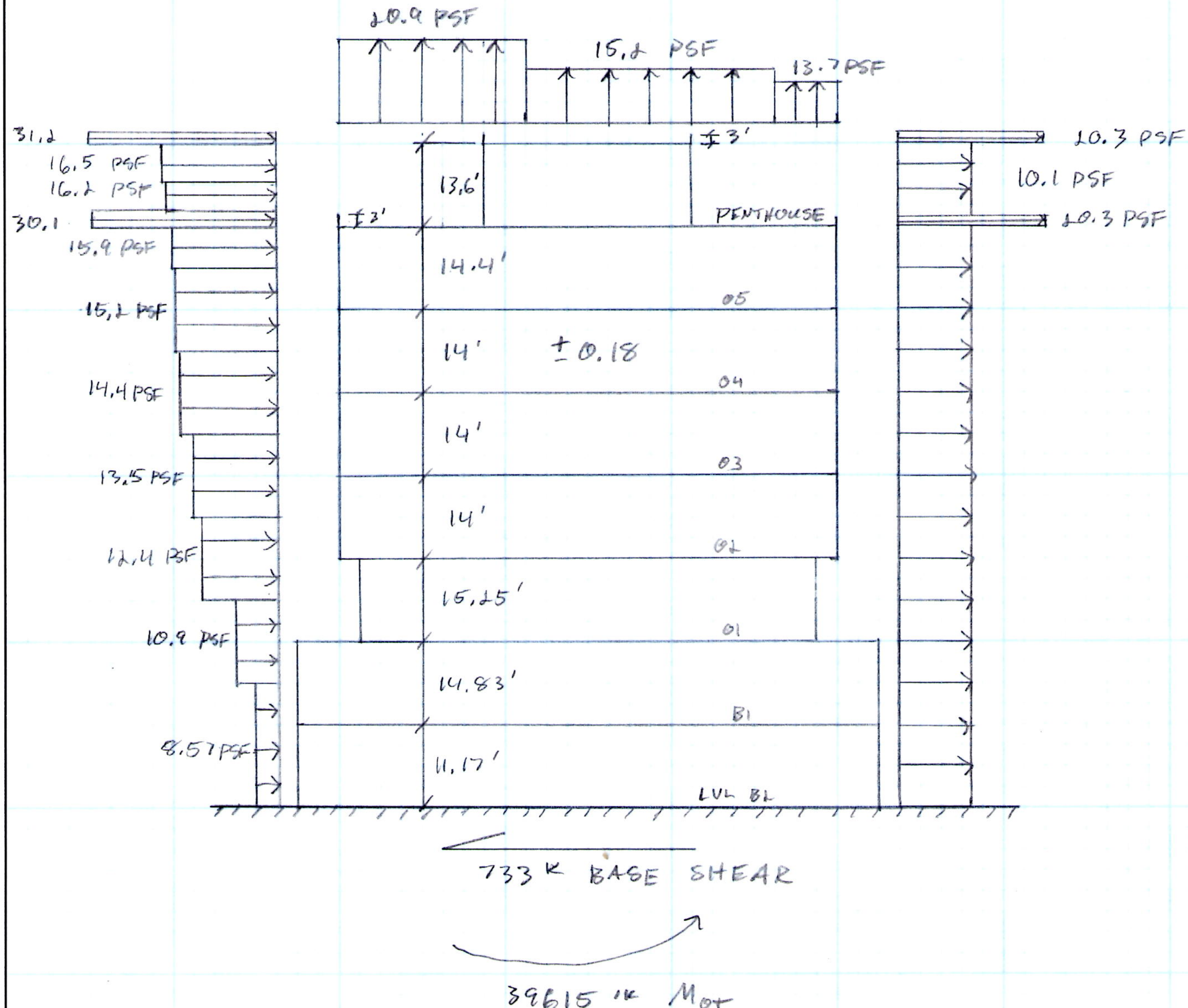
G_f=	1.0	
C_p=	0.8	Windward
	-0.5	Leeward
GC_{pn}=	1.5	Windward
	-1.0	Leeward
q_h=	20.7	ft.

MWFRS ANALYSIS: NE-SW ROOF

Dist. H	0' to 52'	52' to 104'	104' to 208'	>208'
C_p	-1.01	-0.738	-0.662	-0.623
Pressure (PSF)	**-20.9**	**-15.2**	**-13.7**	**-12.9**

SHT:10

WIND DIAGRAM: NE-SW DIRECTION



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PROJECT: RGA GLOBAL HQ TECHNICAL REPORT 2

TITLE: WIND LOAD PRESSURE DIAGRAM

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MWFRS ANALYSIS: NW-SE Walls								
Floor	**z**	**q**	**Windward (PSF)**	**Leeward (PSF)**	**Tribuary Height(ft.)**	**Tributary Area(SF)**	**Story Shear(k)**	**Story M_{OT}(ft.-k)**
B1	11.17	10.7	7.39	-4.79	18.585	2323	28.30	53.1
1	26	13.6	9.41	-4.79	15.04	1579	22.43	414.4
2	41.25	15.6	10.74	-4.79	14.625	1682	26.12	886.3
3	55.25	16.9	11.67	-4.79	14	1610	26.51	1278.9
4	69.25	18.0	12.45	-4.79	14	1610	27.76	1727.9
5	83.25	19.0	13.12	-4.79	14.2	1633	29.25	2227.6
6	97.65	19.9	13.74	-4.79	7.2	828	15.34	1442.7
Tower Parapet	100.65	20.1	30.10	-20.26	3	345	17.37	1722.6
Mean Roof Height	104	20.3	13.99	-4.79	6.975	244	4.58	460.7
T.O. Penthouse	111.25	20.7	14.26	-4.79	3.625	127	2.42	264.5
Penthouse Parapet	114.25	20.8	31.21	-20.26	3	105	5.40	609.3
						Base Shear and M_{OT}=	**205**	**11088**

$p=qG_fC_p-q_i(GC_{pi})$

G_f=	0.863	
C_p=	0.8	Windward
	-0.274	Leeward
GC_{pn}=	1.5	Windward
	-1.0	Leeward
q_h=	20.7	ft.

MWFRS ANALYSIS: NW-SE ROOF				
Dist. H	0' to 52'	52' to 104'	104' to 208'	>208'
C_p	-0.9	-0.9	-0.5	-0.3
Pressure (PSF)	**-16.04**	**-16.04**	**-8.91**	**-5.35**

SHT: 12

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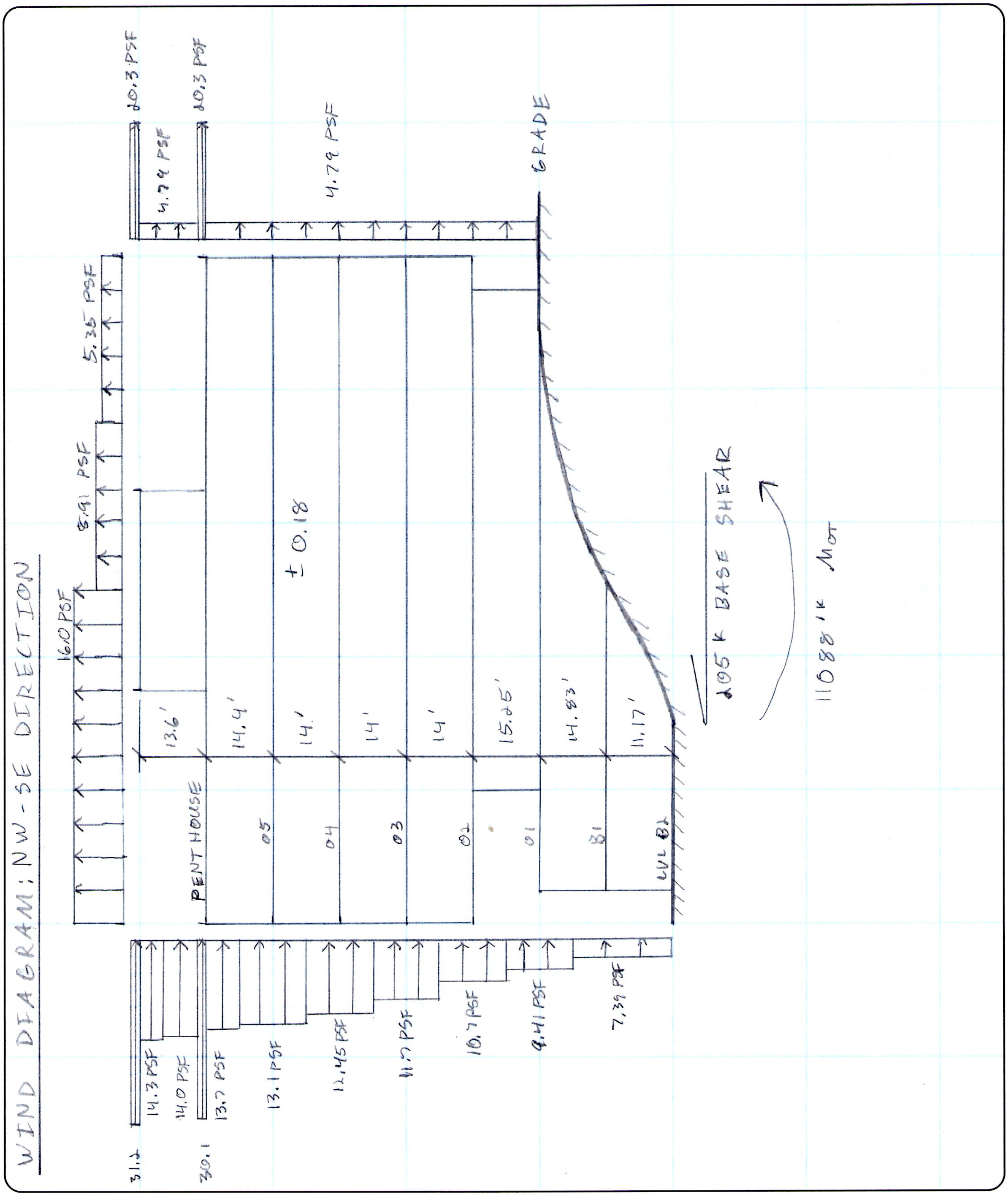

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PROJECT	RGA GLOBAL HQ TECHNICAL REPORT 2
TITLE	WIND LOAD PRESSURE DIAGRAM

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Seismic Loads

This section presents seismic load determination.

SEISMIC LOADING

IS BUILDING EXEMPT?

- BUILDING <u>NOT</u> EXEMPT

DESIGN SPECTRAL RESPONSE

- ACCERATION PARAMETERS [§11.4.1]
  - $S_S = 0.45g$ [ASCE 7-05 FIG. 22-1]
  - $S_1 = 0.10g$ [FIG. 22-2]
- SITE CLASS [§11.4.2]
  - FROM GEOTECH REPORT, UNDRAINED SHEAR STRENGTH TEST YIELDED AN AVERAGE SHEAR STRENGTH >2000 PSF
  - ∴ **SITE CLASS C** [§20.3.3, TABLE 20.3-1]
- ADJUST FOR SITE CLASS

S_S	F_a
0.25	1.2
0.45	1.2
0.50	1.2

∴ $F_a = 1.2$ [TABLE 11.4-1]

- $S_1 = 0.10$ ∴ $F_v = 1.7$ [TABLE 11.4-2]
- $S_{MS} = F_a S_S = 1.2(0.45g) = \mathbf{0.54g}$ [EQN. 11.4-1]
- $S_{M1} = F_v S_1 = 1.7(0.10g) = \mathbf{0.17g}$ [EQN. 11.4-2]

- DETERMINE SPECTRAL PARAMETERS
  - $S_{DS} = 2/3\, S_{MS} = \frac{2}{3}(0.54g) = \mathbf{0.36g}$ [EQN. 11.4-3]
  - $S_{D1} = 2/3\, S_{M1} = 2/3(0.10g) = \mathbf{0.067g}$ [EQN. 11.4-4]

IMPORTANCE FACTOR, I

- OCCUPANCY CATEGORY III
  - ∴ IMPORTANCE FACTOR, **I = 1.25**

SEISMIC DESIGN CATEGORY

- $0.33 < S_{DS} = 0.36 < 50$ ∴ **SDC C** [TABLE 11.6-1]

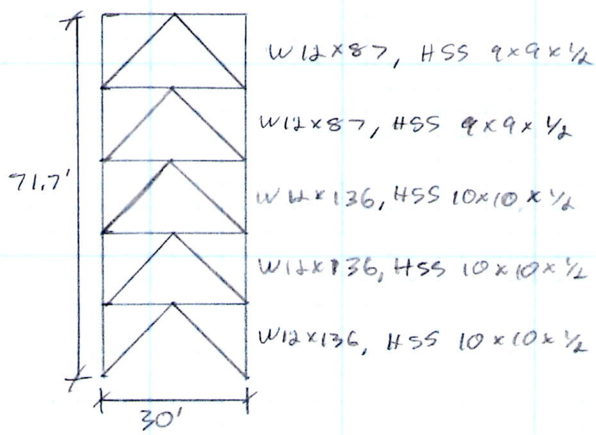
ANALYSIS PROCEDURE SELECTION

- SDC C, OCCUPANCY III ∴ "ALL OTHER STRUCTURES" IN TABLE 12.6-1; ALL PROCEDURES PERMITTED

USE EQUIVALENT LATERAL FORCE ANALYSIS

- DOES BUILDING QUALIFY FOR TWO STAGE ANALYSIS?
  1) IS STIFFNESS OF PARKING GARAGE ≥ 10 TIMES THE STIFFNESS OF THE OFFICE?

BRACED FRAME STIFFNESS



W12x136: $I = 1240 \text{ in}^4$

HSS 10x10x½: $A = 17.2 \text{ in}^2$

$h = 71.7'/5 = 14.3'$

$L = \sqrt{15^2 + 14.3^2} = 20.7'$

$\theta = \tan^{-1}(14.3/15) = 43.6°$

- FROM AE 430 CLASS NOTES:

$$K_{COLS} = \frac{12E(I_1 + I_2)}{h^3} = \frac{12(29000)(2)(1240)}{(14.3 \cdot 12)^3} = 171 \text{ k/in}$$

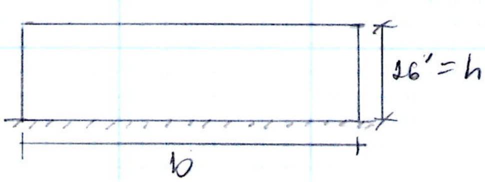
$$K_{BRACE} = \frac{AE}{L}\cos^2\theta = \frac{(17.2)(29000)}{(20.7 \cdot 12)}\cos^2 43.6° = 1053 \text{ k/in}$$

$$K_{BF} = 171 + 1053 = 1224 \text{ k/in}$$

- 8 SIMILAR FRAMES:

$$R_{TOT} = 8/1224 = 0.00653$$

SHEAR WALL STIFFNESS



- ASSUME WALL TOP BEHAVES AS FIXED
- ASSUME G = 0.4E FOR CONC.

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- FROM CLASS NOTES:

$$\circ\ K = \frac{E}{(h/b)^3 + 3(h/b)}$$

$$E = 57000\sqrt{5000psi} = 4031\ KSI$$

○ PLUG IN VALUES FOR DIFFERENT SHEAR WALL LENGTHS:

$$K_{22.7'} = \frac{4031}{(26/22.7)^3 + 3(26/22.7)} = 816\ ^k/_{in} \quad (3\ WALLS)$$

$K_{27.7'} = 1107$ (5 WALLS)
$K_{23'} = 834$ (1 WALL)
$K_{28'} = 1124$ (1 WALL)
$K_{24'} = 892$ (2 WALLS)
$K_{60'} = 2918$ (1 WALL)

$$\Sigma = \frac{5}{1107} + \frac{1}{834} + \frac{1}{1124} + \frac{2}{892} + \frac{3}{816} + \frac{1}{2918} = 0.129$$

COMPARE:

$0.00623(10) = 0.0623 < 0.129$ OK

2) STRUCTURE PERIOD NOT GREATER THAN 1.1 TIMES OFFICE BUILDING PERIOD?

- OFFICE: $T_a = C_t h_n^x = 0.02(85.25)^{0.75} \Rightarrow T_a = 0.516\ s$
  ↳ EXACT DERIVATION LATER
- BUILDING PERIOD NOT GIVEN, ASSUME
  $T < 0.516(1.1) = 0.568$ OK

USE TWO STAGE ANALYSIS

OFFICE STRUCTURE ANALYSIS

- DETERMINE R
  - STEEL SYSTEM NOT SPECIFICALLY DETAILED FOR SEISMIC RESISTANCE $\therefore$ **R = 3** [TABLE 12.2-1]
- FIND APPROX. FUNDAMENTAL PERIOD
  - FROM TABLE 12.8-2 "ALL OTHER SYSTEMS":
    $C_t = 0.02$, $x = 0.75$
  - $h_n = 85.25'$
  - $T_a = C_t h_n^x = 0.02(85.25)^{0.75}$ $\therefore$ **$T_a = 0.561\,s$**
- FIND SEISMIC RESPONSE COEFFICIENT, C_s
  - FIND T_L
    $T_L = 12\,s$ [FROM FIG. 22-15]
  - $T_a < T_L$

    $\therefore C_{s\,max} = \dfrac{S_{D1}}{T_a(R/I)} = \dfrac{0.067}{0.561(3/1.25)} = 0.0498$ [EQN. 12.8-3]
  - $C_s = \dfrac{S_{DS}}{(R/I)} = \dfrac{0.36}{(3/1.25)} = 0.15$ [EQN. 12.8-2]

  $\therefore$ **$C_s = 0.0498$**
- DETERMINE SEISMIC WEIGHT
  - TYPICAL ROOF
    $W = (98\text{ PSF})(290')(115')(1/1000) = 3268^k$
  - TYPICAL CURTAIN WALL
    $W = (226\text{ PLF})[(2\cdot290' + 2\cdot115')(4\text{ FLOORS}) + (2\cdot35' + 2\cdot140') + (2\cdot245' + 2\cdot105')](1/1000)$
    $W = 970^k$
  - TYPICAL FLOOR
    $W = (56\text{ PSF})[(115'\cdot290')(4\text{ FLOORS}) + (245'\cdot105')](1/1000)$
    $W = 9048^k$
  - STEEL WEIGHT
    $W = (12\text{ PSF})[115'\cdot290'(5\text{ LEVELS}) + 35'\cdot140'](1/1000)$
    $W = 2060^k$

$\therefore$ **$W_{TOT} = 15300^k$**

• DETERMINE SEISMIC BASE SHEAR

$V_{OFFICE} = C_s W = 0.0498(15300^k)$ ∴ $V_{OFFICE} = 762^k$ [EQN 12.8-1]

• DETERMINE REDUNDANCY FACTOR, ρ

- $\rho = 1.0$ SDC C [§12.3.4.1 #1]

PARKING STRUCTURE ANALYSIS

• DETERMINE R

- ORDINARY R.C. BEARING SHEAR WALL ∴ $R = 4$ [TABLE 12.2-1]

• FIND APPROX. FUNDAMENTAL PERIOD

- FROM §12.8.2.1 *SEE EXCEL NEXT PAGE FOR T_a CALCULATION*

$$T_a = \frac{0.0019}{\sqrt{C_w}} h_n \quad , \quad C_w = \frac{100}{A_b} \sum_{i=1}^{x} \left(\frac{h_n}{h_i}\right)^2 \frac{A_i}{\left[1 + 0.83\left(\frac{h_i}{D_i}\right)^2\right]}$$ [EQNS 12.8-9 + 12.8-10]

- USE T_a THAT WILL CAUSE WORSE CASE ∴ $T_a = 0.047$ s

• FIND SEISMIC RESPONSE COEFFICIENT, C_s

- $T_L = 12$ s (FROM PREVIOUS)

- $C_{s\,max} = \frac{S_{D1}}{T_a (R/I)} = \frac{0.067}{0.0047(4/1.25)} = 0.445$

- $C_s = \frac{S_{DS}}{R/I} = \frac{0.36}{4/1.25} = 0.113$ ∴ $C_s = 0.113$

• DETERMINE SEISMIC WEIGHT

- LEVEL 01:

$w = (253\text{ PSF})(242184\text{ SF})(1/1000) = 61300^k$
↳ FLOOR ↳ FROM REVIT

$w = (1112\text{ PLF})(4567\text{ FT})(1/1000) = 5080^k$
↳ WALL ↳ FROM REVIT

$W_{01} = 66400^k$

- LEVEL B1:

$W = (142\text{ PSF})(242184\text{ SF})(1/1000) = 34400^k$

$W_{wall} = (1112\text{ PLF} + 1117\text{ PLF})(4567')(1/1000) = 10200^k$

$W_{B1} = 44600^k$

- LEVEL B2:

$W = (192\text{ PSF})(242184\text{ SF})(1/1000) = 46500^k$

$W = (1117\text{ PLF})(4567')(1/1000) = 5100^k$

$W_{B2} = 51600^k$

∴ $W_{TOT} = 162600^k$

A_b=	242184	SF
h_n=	26	ft
h_i=	26	ft

APPROX. FUNDAMENTAL PERIOD: PARKING				
SW #	D_i	A_i	NW-SE Dir.	NE-SW Dir.
1	22.7	589	-	282
2	27.7	719	415	-
3	27.7	719	415	-
4	22.7	589	-	282
5	55.7	1447	1225	-
	22.7	589	-	282
6	23.0	598	-	290
7	28.0	728	-	424
8	24.0	624	316	-
9	24.0	624	316	-
10	60.0	1560	-	1350
		Sum=	2688	1560
		C_w=	1.110	0.644
		T_a=	**0.047**	0.062

- DETERMINE SEISMIC BASE SHEAR

$V_{PARKING} = C_S W = 0.113 (162600^K)$ ∴ $V_{PARKING} = 18900^K$

- REDUNDANCY FACTOR

$\rho = 1.0$ SDC C [§12.3.4.1]

DETERMINE BASE SHEAR

- DETERMINE AMPLIFICATION RATIO

$$\frac{R/\rho \text{ (OFFICE)}}{R/\rho \text{ (PARKING)}} = \frac{R_{OFFICE}}{R_{PARKING}} = \frac{3}{4} = 0.75 < 1 \therefore 1.0$$

- DETERMINE BASE SHEAR

$V_{BASE} = V_{OFFICE} (2 \text{ BLDGS})(1.0) + V_{PARKING}$

$V_{BASE} = 2(762^K)(1.0) + 18900^K \Rightarrow V_{BASE} = 20400^K$

DETERMINE STORY FORCES

- DETERMINE K
  - OFFICE: $T_a = 0.561s$

K = 1.03

0.5	1
0.561	1.03
2.5	2

$$\frac{2-1}{2.5-0.5}(0.561-0.5)+1$$

  - PARKING: $T_a = 0.047s < 0.5s$ ∴ $K = 0.5$

- SEE FOLLOWING EXCEL FOR STORY FORCE DETRMINATION

WIND VS. SEISMIC

WIND $V_b = 733^K$ < SEISMIC $= 20400^K$

∴ **SEISMIC CONTROLS**

k_{office}= 1.03

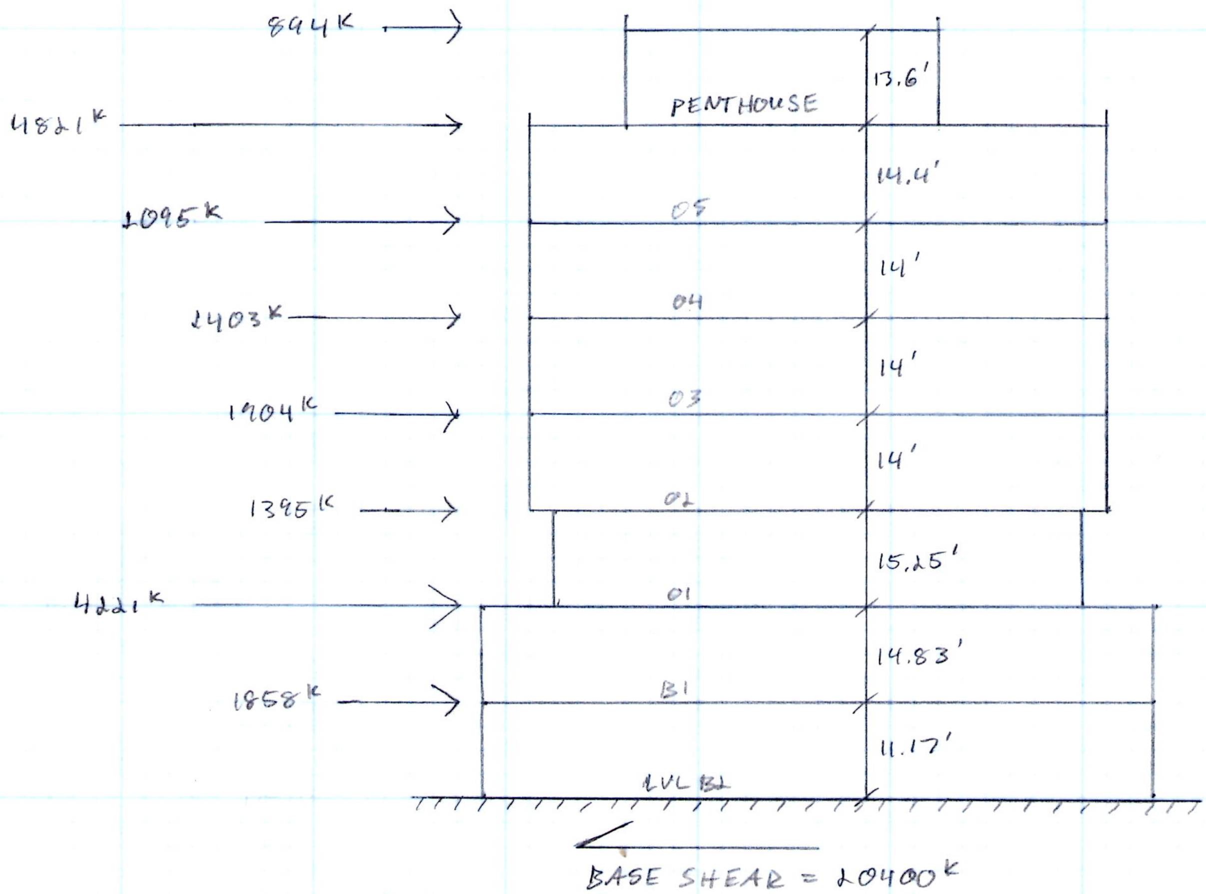
$k_{parking}$= 0.5

V= 20400 k

SEISMIC STORY FORCES					
Level	w_x(k)	h_x(ft)	$w_x h_x^k$(ft-k)	C_{vx}	F_x(k)
B1	44600	11.2	149060	0.091	**1858**
1	66400	26.0	338575	0.207	**4221**
2	2426	41.3	111886	0.068	**1395**
3	2451	55.3	152729	0.093	**1904**
4	2451	69.3	192731	0.118	**2403**
5	2451	83.3	232978	0.142	**2905**
Penthouse	3451	97.7	386681	0.236	**4821**
PH Roof	559.3	111.3	71669	0.044	**894**
		$\Sigma w_x h_x^k$=	1636309	1	**20400**

SHT: 9

SEISMIC STORY FORCE DISTRIBUTION



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PROJECT	RGA GLOBAL HQ TECHNICAL REPORT 2
TITLE	SEISMIC LOAD STORY FORCE DIAGRAM

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