Letter of Transmittal

Jeremy Swartz

September 22, 2017

Dr. Aly Said
The Pennsylvania State University
209 Engineering Unit A

Dear Dr. Said,

The following report, Structural Notebook Submission A, is the first of a three part evaluation of One City Center in Washington D.C. The report consists of a site plan and a comprehensive analysis of the gravity and lateral loads acting on the structure. Inside the gravity section are the analyzed floor and roof dead loads, the wall loads, snow loads and live loads. The lateral section consists of a wind pressure and story force analysis as well as a seismic load analysis.

Thank you for your evaluation of this report. Please let me know if you have any questions regarding the material. I look forward to improving this report based on your feedback.

Sincerely,

Jeremy Swartz

COURTESY OF CLARKE CONSTRUCTION

One and Two City Center Washington D.C.

Notebook Submission A

Building Codes, Specifications and Loads

Report 2

By: Jeremy Swartz

Option: Structural

Advisor: Dr. Aly Said

1. Executive Summary

One and Two City Center are commercial buildings that are a part of a multi-use development located in Washington D.C…Being approximately 312,000 square feet the building is part of a four lot project. Planning and Design began as early as April 2007 but due to the recession construction was delayed until April of 2011 and was finished later in 2014.

The twin office buildings now stand 12 stories tall with a floor to floor height of 12'. The shell of the structures is a glazed aluminum curtain wall with movable louvers. Like many roofs in D.C. there is a rooftop mezzanine on both One and Two City Center with several areas used as a green roof. Connecting the two buildings on every floor are glass coated walkways which span the alleyway separating the One and Two City Center. The building has achieved LEED Gold certification and the development has been one of the first to achieve LEED-ND (Neighborhood Development) certification.

The structural floor systems are two way post tensioned concrete slabs supported by typical 24" x 24" concrete columns. These columns run down through the building into the below grade parking and come to rest on shallow concrete footers. Lateral Loads are resisted by a series of shear walls which surround the elevators and stairwells. The glazed aluminum curtain wall is fastened to the structure at the concrete slab and supported by HSS sections. The penthouse roof and floor are supported by a series of w10's.

The additional lots feature commercial, residential, parking and public areas. To the north of One and Two City Center (Lot46) is an outside plaza with a captivating reflecting pool. To the east of the site is a four structure commercial and residential development (Lot 47). The two main lots are connected by an alleyway lined with retail stores. At the center of Lot 47 is a small courtyard offering relief from the city. Underneath Lot 46 and 47 is a four story parking garage for public access and the use of delivery trucks.

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Site Plan

One and Two City Center are located in the downtown area of Washington D.C. The site is a part of a larger development shown in figure one below. The entire development sits on four stories of below grade parking. The two office buildings are connected by a series of bridges which span the alleyway separating them.

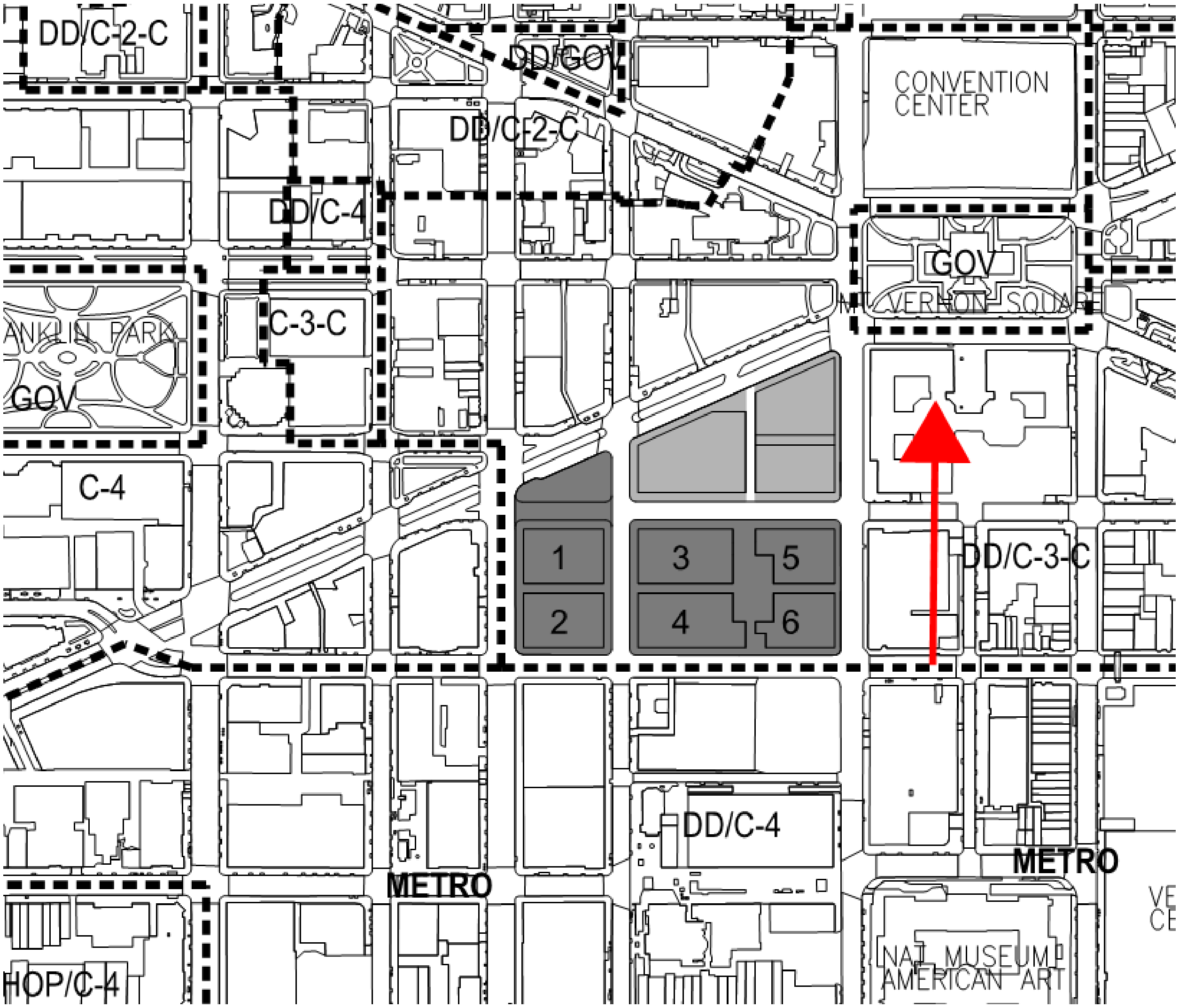
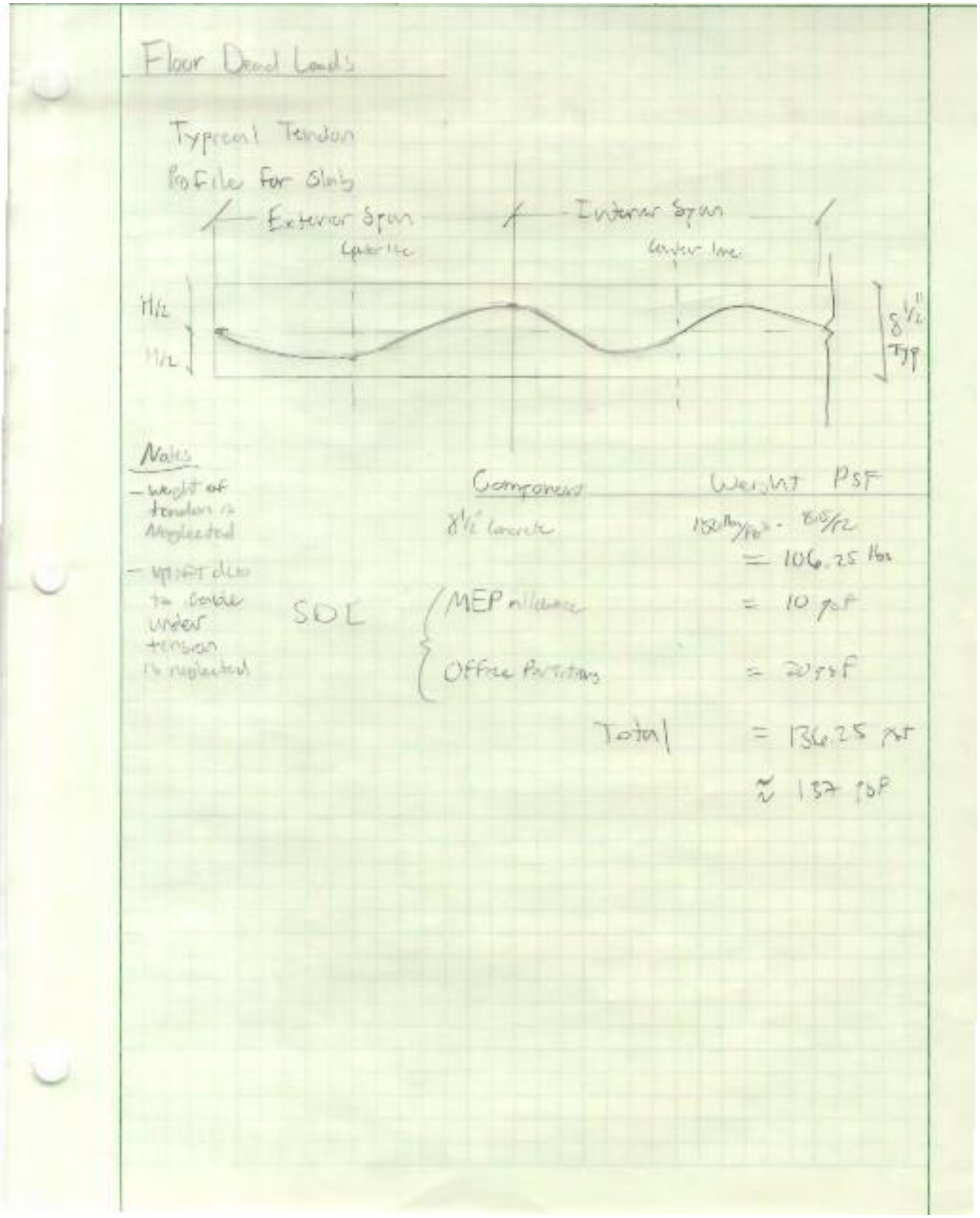


Figure 1: A plan view of the buildings inside the development shaded grey.

1. Gravity Loads

1.1 Floor Loads



Floor Dead Loads

Typical Tendon Profile for Slab

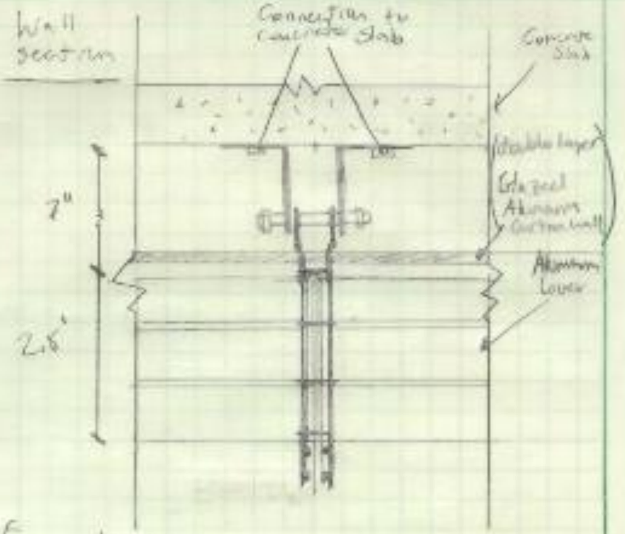
Notes

- weight of tendon is Neglected
- uplift due to cable under tension is neglected

Component	Weight PSF
8 1/2" Concrete	150 lbs/ft³ · 8.5/12 = 106.25 lbs
SDL { MEP allowance	= 10 psf
Office Partitions	= 20 psf
Total	= 136.25 psf ≈ 137 psf

1.2 Wall Loads

Wall Loads



Curtain Wall

Material	Weight
- Glazed Aluminum Curtain wall (from URL Aluminum Curtainwall)	= 9.75 psf
- Aluminum Lovers	= 0.25 psf (calculation below)

Lowers
- length varies, largest length is about 15'
- Width varies by height Average is 2.8'

Architectural Lovers data sheets

$4' \times 4' = 4.11 lb/ft^2$

$16 ft^2 = 4 lbs/ft^2$

$1 ft^2 = 0.25 lbs/ft^2$

Total = two faced curtain wall

$2 \times (9.75)$

+ Horizontal louvers (0.25)
+ Vertical Louvers (0.25)

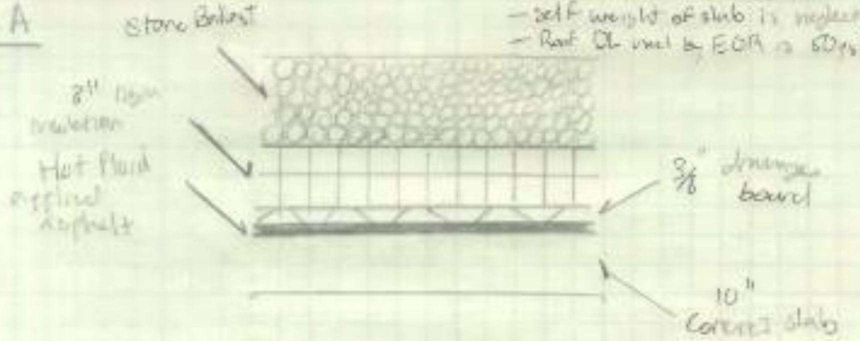
= 20 psf

1.3 Roof Loads

Roof Dead Loads

General Notes
- Uplift due to Post tensioned system not accounted for
- material weight from technical data sheets
- self weight of slab is neglected
- Roof DL used by EOR is 60psf

Type A



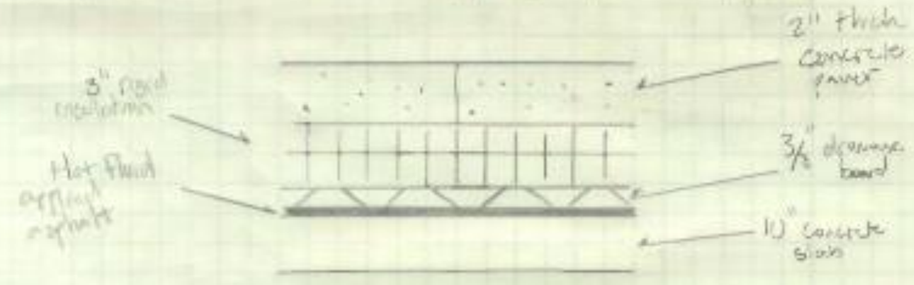
Material	Weight Psf
- 8" rigid insulation	1" = 0.5 psf = 4.5 psf (Base cascade data)
- Stone Ballast	= 8.7 psf (Base cascade data)
- Hot fluid applied asphalt	= 1.53 psf (215 mils, from Carlisle technical data)
- Drainage board	= 2.5 psf (Carlisle datasheet)

☆ Ignoring ☆
Self weight of Slab
= 150 × 10/12
= 125 psf

Total = 17.23 psf
≈ 17.5 psf

Type B/D

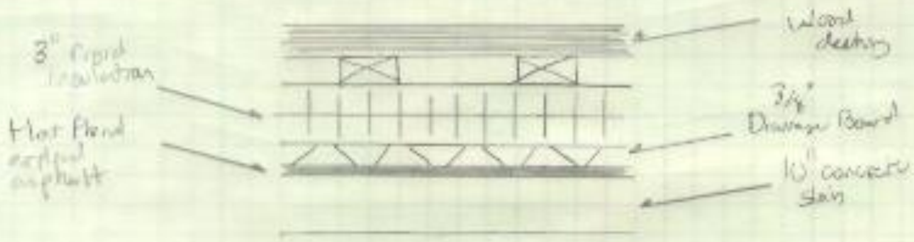
Note: Type B and D are similar
except B has concrete pavers and
type D has stone pavers



Material	Weight (Psf)	Weight (Psf)
- 2" thick Concrete Pavers (assumed Lightweight)	$115\ lbs/ft^3 \cdot 2''/12''$ = 19.2 psf	(Cold spring data sheet) = 15 psf
- 3" Rigid insulation	= 4.5 psf	= 4.5
- Hot fluid applied asphalt	= 1.53 psf	= 1.53
- Drainage board	= 2.5 psf	= 2.5
	Total = 27.73 psf ≈ 28 psf	= 23.83 psf ≈ 24 psf
	Type B	Type D

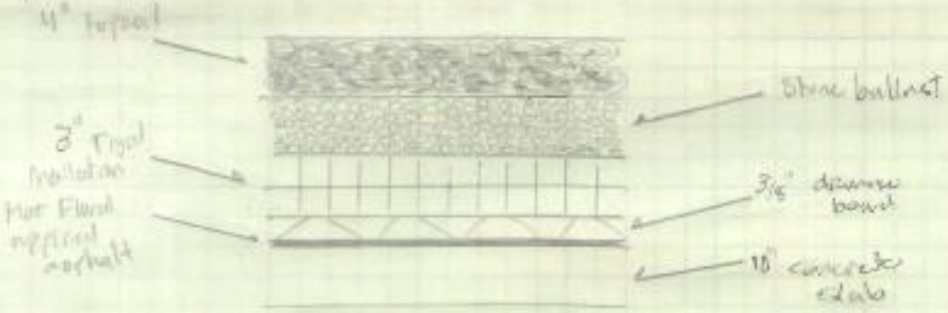
Type C

1x9 on 2x4



Material	Weight (PSF)	
- 1" Hardwood Decking	= 4 psf	(Boise Cascade)
- 2"x4" Sleepers	= 1.1 psf	(Boise Cascade
- 3" rigid insulation	= 4.5 psf	
- 3/8" Drainage Board	= 2.5 psf	
- Hot Fluid applied asphalt	= 1.53 psf	
Total	= 14.13 psf	
	≈ 15 psf	

Type E

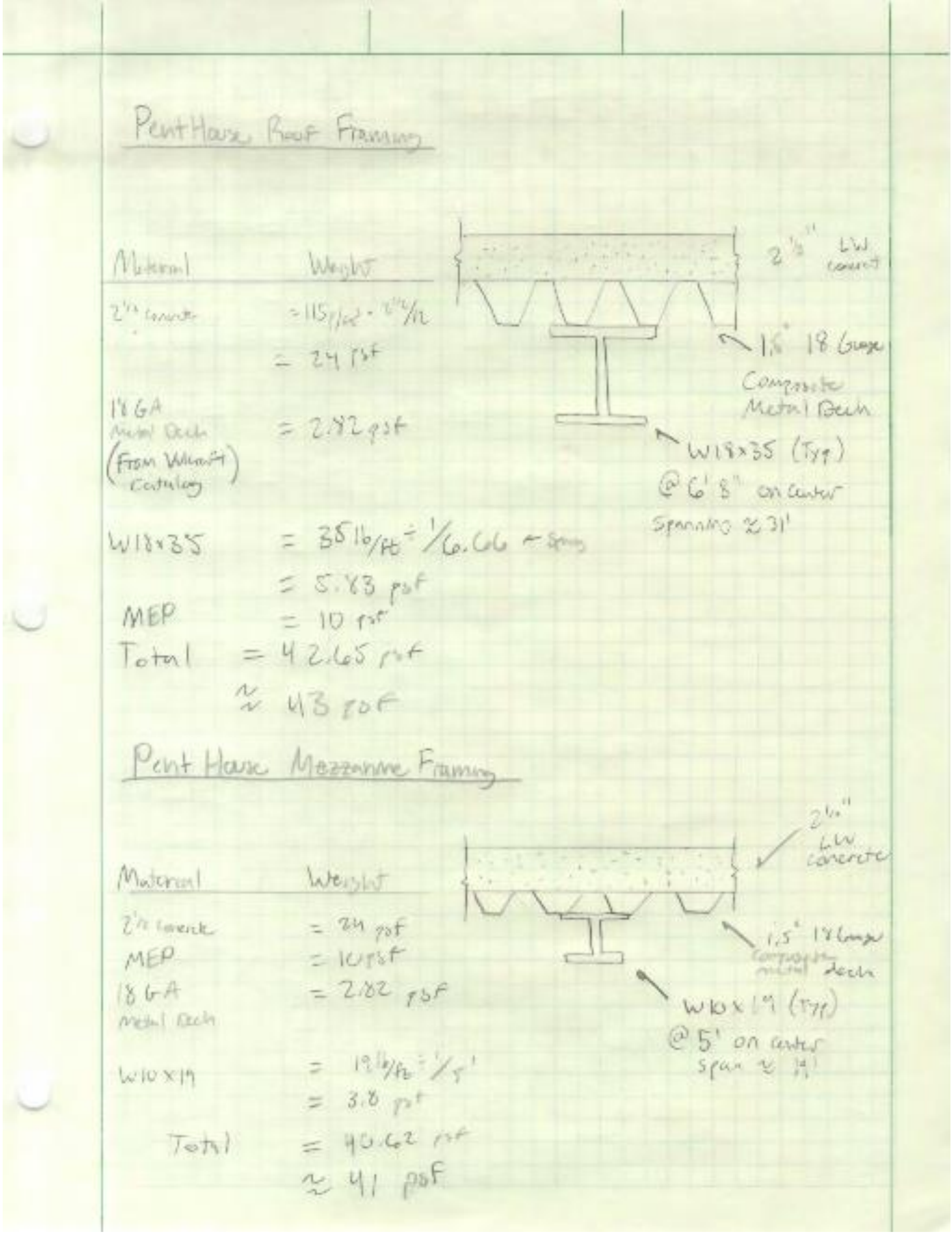


Material	Weight (PSF)
- 4" Topsoil (0-4 blows per ft)	70-100 lbs/ft³ (Geotechnicalinfo.com) 85 lbs/ft³ · 4"/12 = 28.3 psf
- Stone ballast	= 8.7 psf
- 3" Rigid Insulation	= 4.5 psf
- Drainage board	= 2.5 psf
- Hot Fluid applied Asphalt	= 1.53 psf

Total = 45.53 psf

≈ 46 psf

<u>Note</u>: EOR used 50 psf for Green Roof



PentHouse Roof Framing

Material	Weight
2½" concrete	= 115 pcf · 2½"/12 = 24 psf
18 GA Metal Deck (From Vulcraft Catalog)	= 2.82 psf
W18x35	= 35 lb/ft ÷ 1/6.66 ← Spacing = 5.83 psf
MEP	= 10 psf
Total	= 42.65 psf ≈ 43 psf

2½" LW concrete

1.5" 18 Gauge Composite Metal Deck

W18x35 (Typ) @ 6' 8" on center Spanning ≈ 31'

Pent House Mezzanine Framing

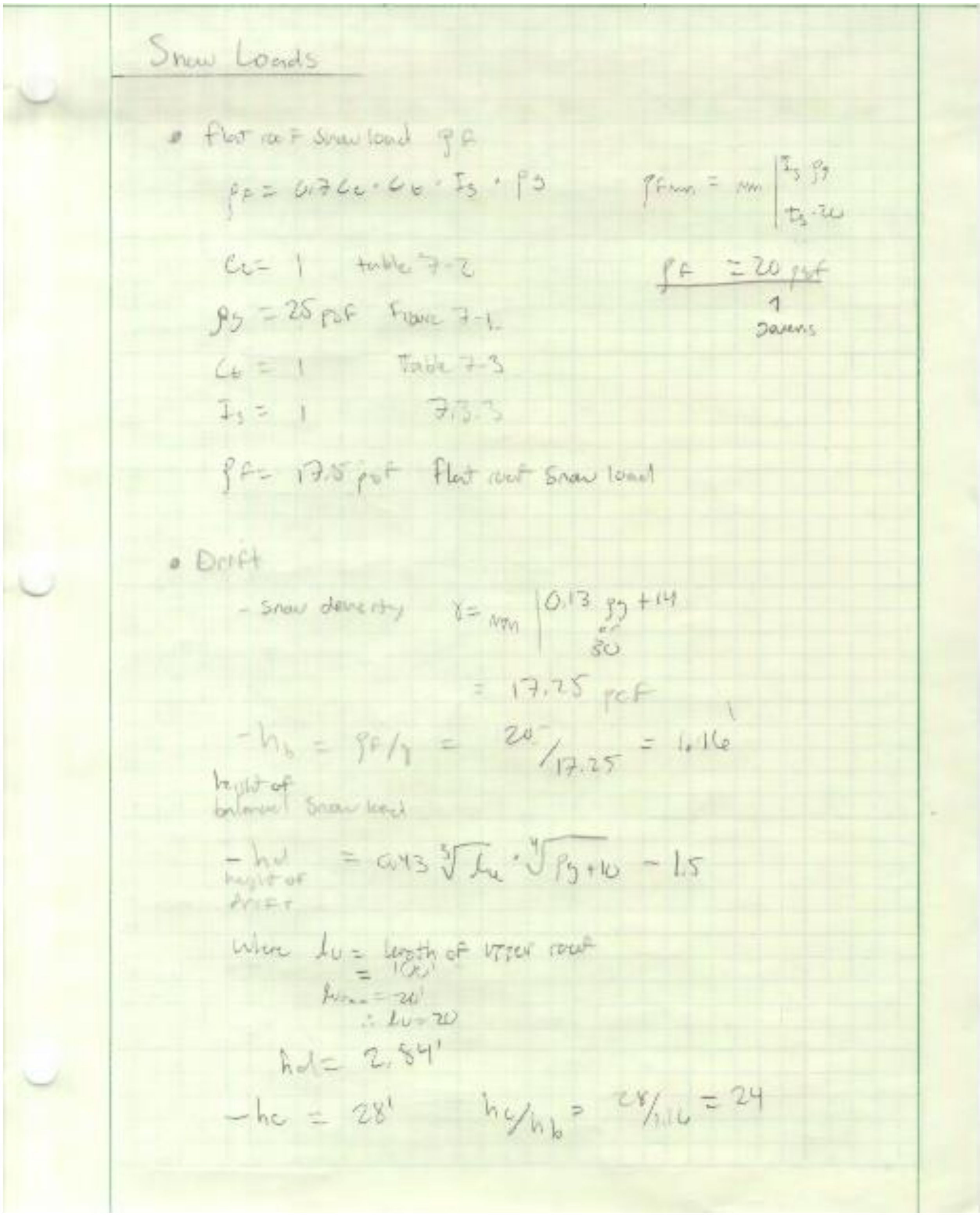
Material	Weight
2½" concrete	= 24 psf
MEP	= 10 psf
18 GA Metal Deck	= 2.82 psf
W10x19	= 19 lb/ft ÷ 1/5' = 3.8 psf
Total	= 40.62 psf ≈ 41 psf

2½" LW concrete

1.5" 18 Gauge Composite metal deck

W10x19 (Typ) @ 5' on center span ≈ 14'

1.4 Snow Loads



Snow Loads

- flat roof snow load p_f

$p_f = 0.7 C_e \cdot C_t \cdot I_s \cdot p_g$ $\quad p_{f\,min} = \min \left| \begin{array}{l} I_s\, p_g \\ I_s \cdot 20 \end{array} \right.$

$C_e = 1$ table 7-2 $\quad \underline{p_f = 20\text{ psf}}$

$\uparrow$ governs

$p_g = 25$ psf figure 7-1

$C_t = 1$ Table 7-3

$I_s = 1$ 7.3.3

$p_f = 17.5$ psf flat roof snow load

- Drift

\- snow density $\gamma = \min \left| \begin{array}{l} 0.13\, p_g + 14 \\ \text{or} \\ 30 \end{array} \right.$

$= 17.25$ pcf

\- $h_b = p_f / \gamma = 20 / 17.25 = 1.16'$

height of balanced snow load

\- $h_d = 0.43 \sqrt[3]{l_u} \cdot \sqrt[4]{p_g + 10} - 1.5$

height of drift

where l_u = length of upper roof

= [illegible]

$l_{u\,min} = 20'$

$\therefore l_u = 20$

$h_d = 2.84'$

\- $h_c = 28'$ $\quad h_c / h_b = 28/1.16 = 24$

Note: The spacing of adjacent buildings is >20'
∴ drift from other structures is neglected.

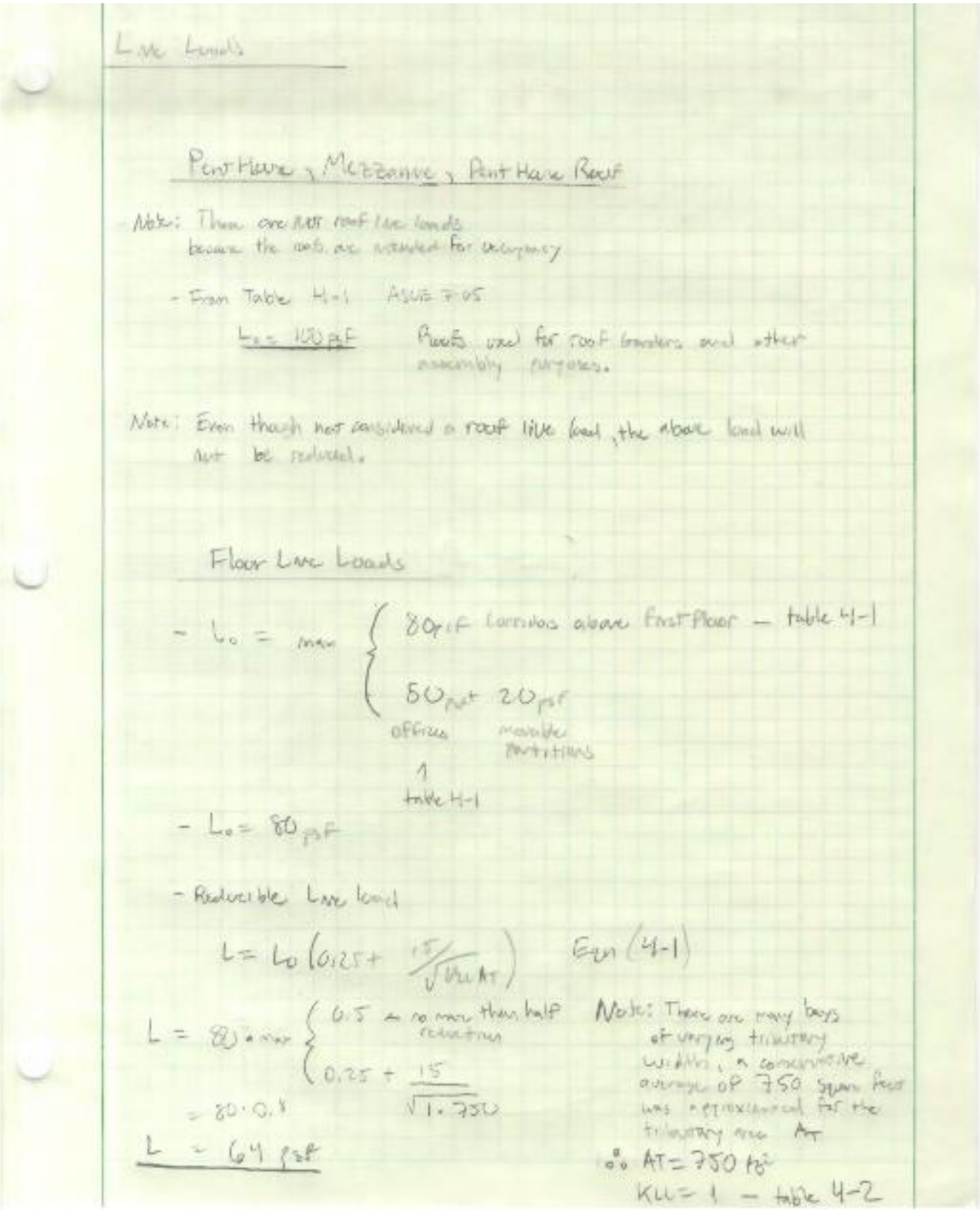
- because $h_d < h_c$

$w_{width} = 4 h_d$
$= 4 \times 2.84$
$= 11.36'$

$p_d = \gamma h_d$
$= 17.25 \times 2.84$
$= 50$ PSF

Diagram

1.5 Live Loads



Live Loads

Pent House, Mezzanine, Pent House Roof

Note: There are not roof live loads
because the roofs are intended for occupancy

- From Table 4-1 ASCE 7-05

L_o = 100 psf — Roofs used for roof gardens and other assembly purposes.

Note: Even though not considered a roof live load, the above load will not be reduced.

Floor Live Loads

$$- L_o = \max\begin{cases} 80\text{ psf} & \text{Corridors above First Floor — table 4-1} \\ \underset{\text{offices}}{50_{psf}} + \underset{\text{movable partitions}}{20_{psf}} & \end{cases}$$

↑ table 4-1

- $L_o = 80_{psf}$

- Reducible Live load

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right) \quad \text{Eqn } (4\text{-}1)$$

$$L = 80 \cdot \max\begin{cases} 0.5 \leftarrow \text{no more than half reduction} \\ 0.25 + \dfrac{15}{\sqrt{1 \cdot 750}} \end{cases}$$

$= 80 \cdot 0.8$

$\underline{L = 64\text{ psf}}$

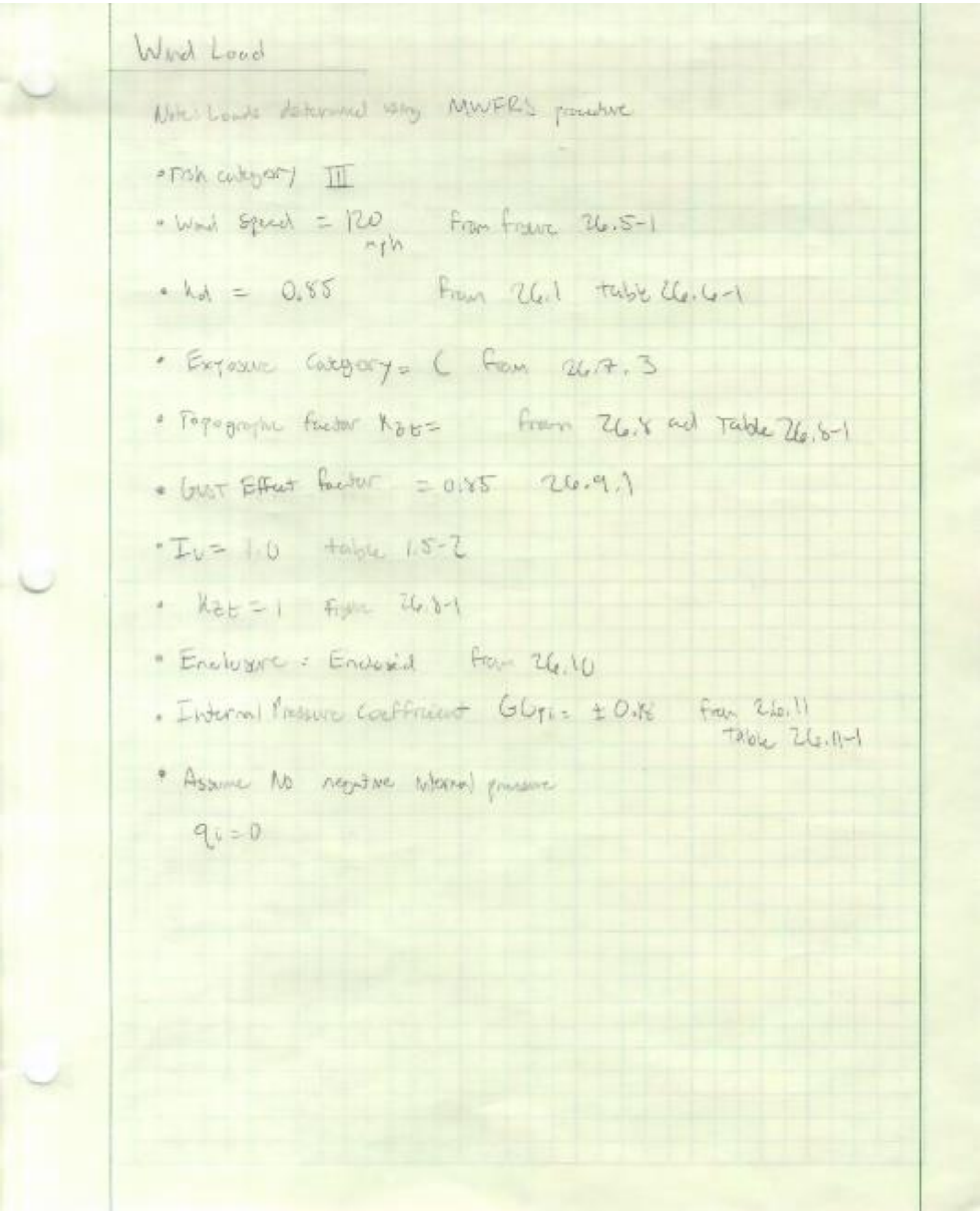
Note: There are many bays of varying tributary widths, a conservative average of 750 square feet was approximated for the tributary area A_T

$\therefore A_T = 750\text{ ft}^2$

$K_{LL} = 1$ — table 4-2

2. Lateral Loads

2.1 Wind Loads



Wind Load

Note: Loads determined using MWFRS procedure

- Risk category III
- Wind Speed = 120 mph from figure 26.5-1
- K_d = 0.85 from 26.1 table 26.6-1
- Exposure Category = C from 26.7.3
- Topographic factor K_{zt} = from 26.8 and Table 26.8-1
- Gust Effect factor = 0.85 26.9.1
- I_w = 1.0 table 1.5-2
- K_{zt} = 1 figure 26.8-1
- Enclosure = Enclosed from 26.10
- Internal Pressure Coefficient GC_{pi} = ± 0.18 from 26.11 Table 26.11-1
- Assume No negative internal pressure

  $q_i = 0$

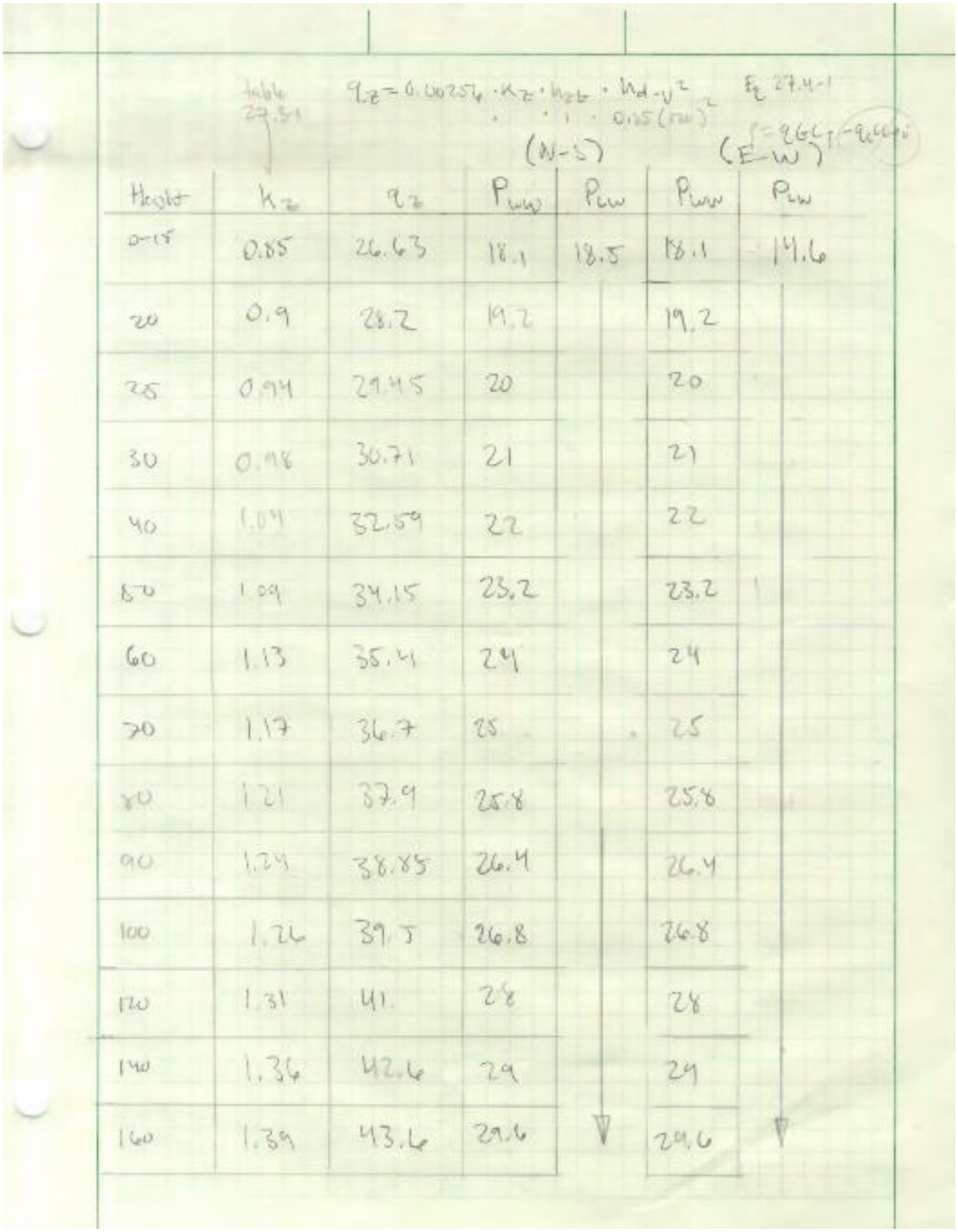


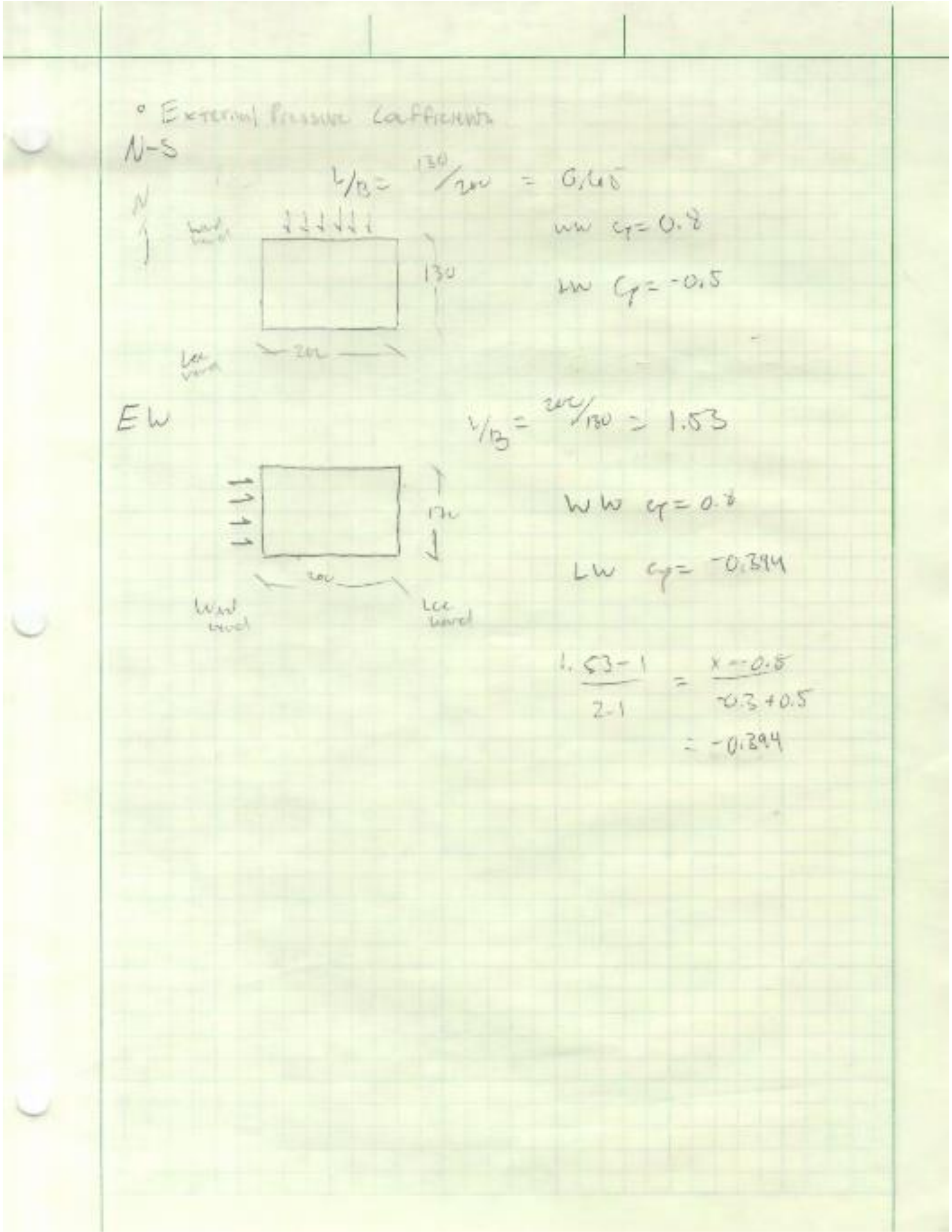
table 27.3.1

$q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2$ Eq 27.4-1

$\cdot \quad \cdot 1 \cdot 0.85 (\text{[illegible]})^2$

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

Height	K_z	q_z	P_{ww} (N-S)	P_{LW} (N-S)	P_{ww} (E-W)	P_{LW} (E-W)
0-15	0.85	26.63	18.1	18.5	18.1	14.6
20	0.9	28.2	19.2		19.2	
25	0.94	29.45	20		20	
30	0.98	30.71	21		21	
40	1.04	32.59	22		22	
50	1.09	34.15	23.2		23.2	
60	1.13	35.4	24		24	
70	1.17	36.7	25		25	
80	1.21	37.9	25.8		25.8	
90	1.24	38.85	26.4		26.4	
100	1.26	39.5	26.8		26.8	
120	1.31	41.	28		28	
140	1.36	42.6	29		29	
160	1.39	43.6	29.6	↓	29.6	↓



- External Pressure Coefficients

N-S

$L/B = 130/200 = 0.65$

WW $C_p = 0.8$

LW $C_p = -0.5$

EW

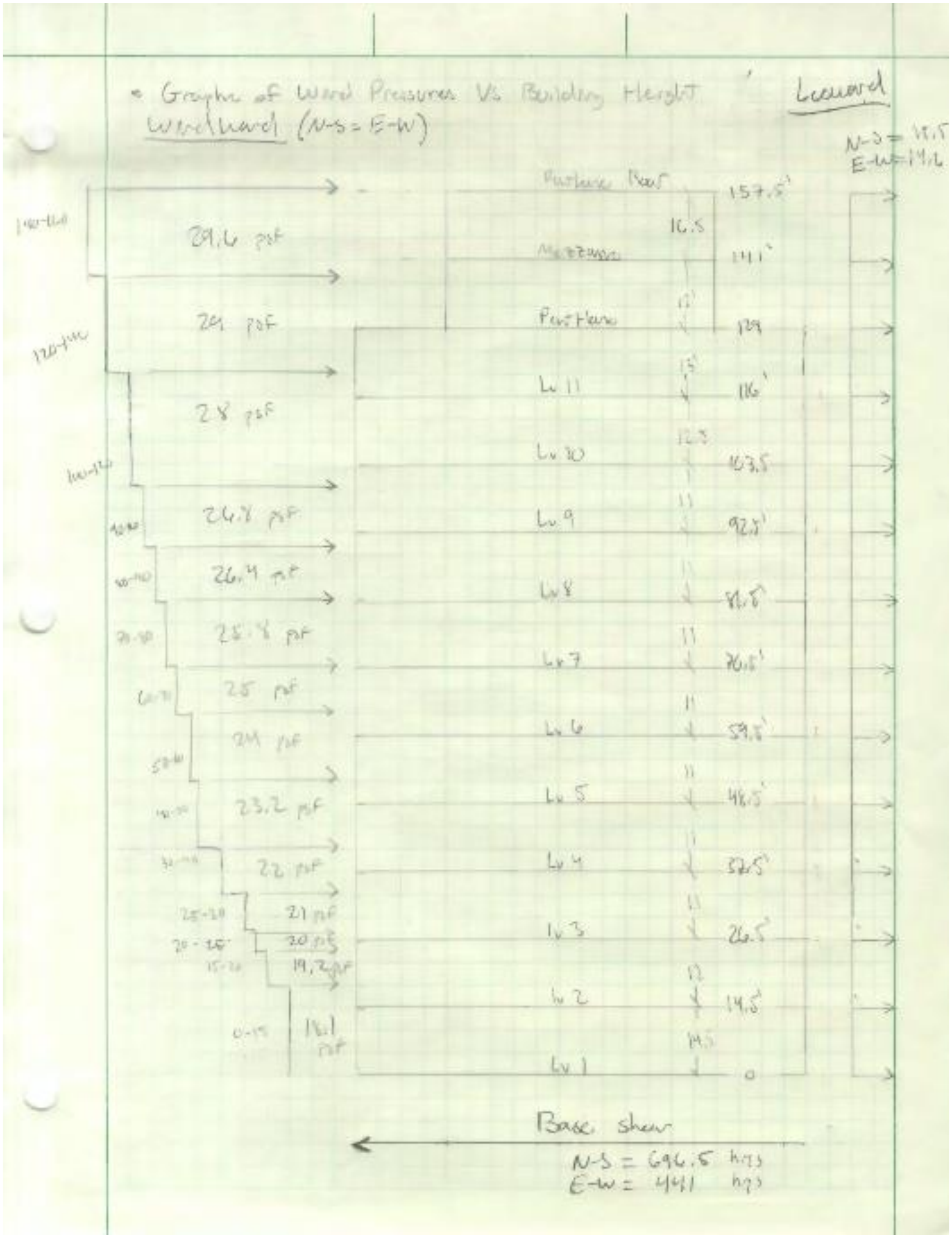
$L/B = 200/130 = 1.53$

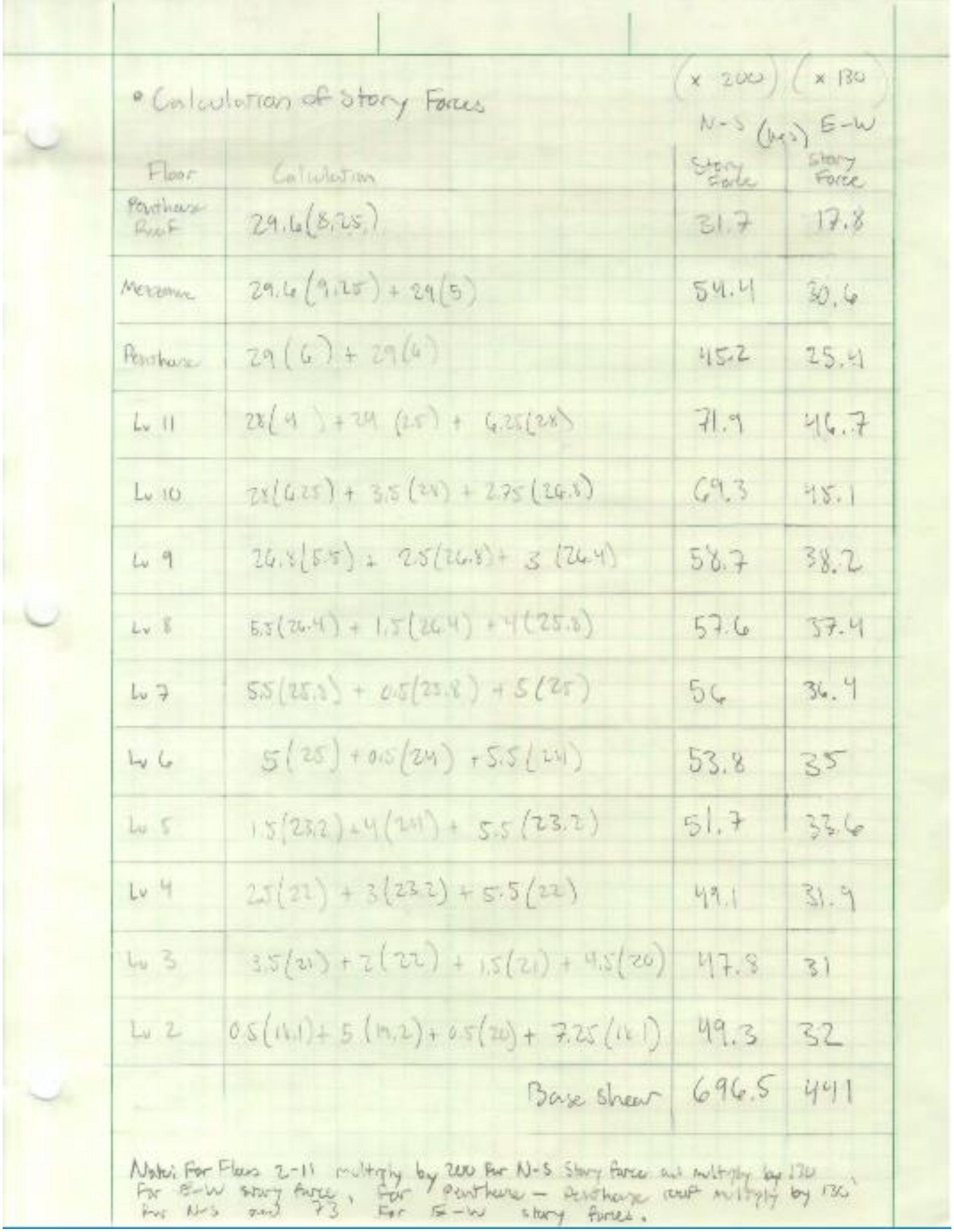
WW $C_p = 0.8$

LW $C_p = -0.394$

$$\frac{1.53-1}{2-1} = \frac{x - -0.5}{-0.3+0.5}$$

$$= -0.394$$


• Graphs of Wind Pressures Vs Building Height
Windward (N-S = E-W)
Leeward
N-S = 15.5
E-W = 14.6
140-160
29.6 psf
120-140
29 psf
100-120
28 psf
90-100
26.8 psf
80-90
26.4 psf
70-80
25.8 psf
60-70
25 psf
50-60
24 psf
40-50
23.2 psf
30-40
22 psf
25-30
21 psf
20-25
20 psf
15-20
19.2 psf
0-15
16.1 psf
Penthouse Roof
157.5'
16.5
Mezzanine
141'
12'
Penthouse
129
13'
Lv 11
116'
12.5
Lv 10
103.5'
11
Lv 9
92.5'
11
Lv 8
81.5'
11
Lv 7
70.5'
11
Lv 6
59.5'
11
Lv 5
48.5'
11
Lv 4
37.5'
11
Lv 3
26.5'
12
Lv 2
14.5'
14.5
Lv 1
0
Base shear
N-S = 696.5 kips
E-W = 441 kips

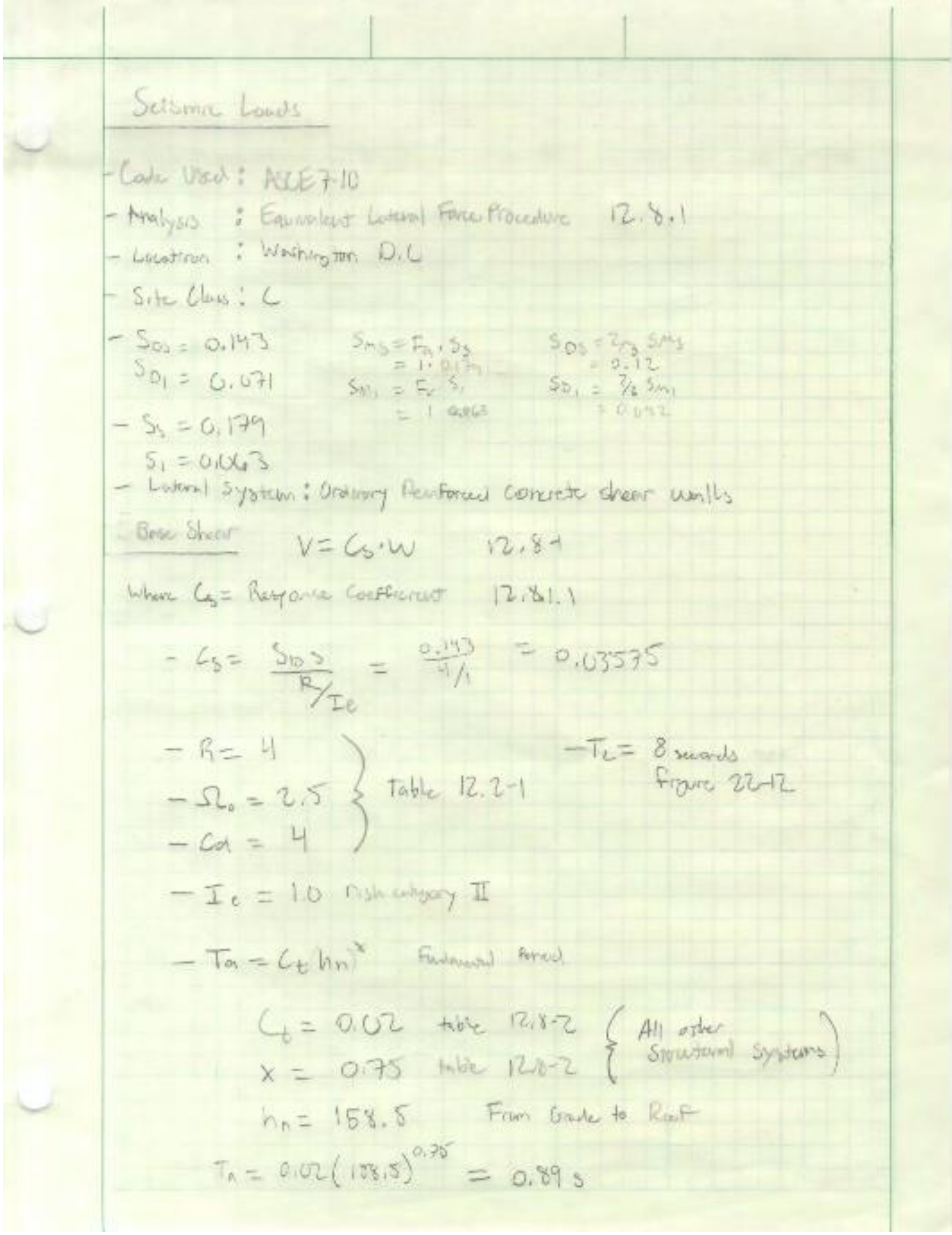


• Calculation of Story Forces

Floor	Calculation	(x 200) N-S (kips) Story Force	(x 130) E-W Story Force
Penthouse Roof	29.6(8.25)	31.7	17.8
Mezzanine	29.6 (9.25) + 29(5)	54.4	30.6
Penthouse	29 (6) + 29(4)	45.2	25.4
Lv 11	28(4) + 29 (2.5) + 6.25(28)	71.9	46.7
Lv 10	28(6.25) + 3.5 (28) + 2.75 (26.8)	69.3	45.1
Lv 9	26.8(5.5) + 2.5(26.8) + 3 (26.4)	58.7	38.2
Lv 8	5.5(26.4) + 1.5(26.4) + 4(25.8)	57.6	37.4
Lv 7	5.5(25.3) + 0.5(23.8) + 5(25)	56	36.4
Lv 6	5(25) + 0.5(24) + 5.5(24)	53.8	35
Lv 5	1.5(23.2) + 4(24) + 5.5 (23.2)	51.7	33.6
Lv 4	2.5(22) + 3(23.2) + 5.5(22)	49.1	31.9
Lv 3	3.5(21) + 2(22) + 1.5(21) + 4.5(20)	47.8	31
Lv 2	0.5(16.1) + 5 (19.2) + 0.5(20) + 7.25 (16.1)	49.3	32
	Base shear	696.5	441

Note: For Floors 2-11 multiply by 200 for N-S Story force and multiply by 130 for E-W story force, for Penthouse – Penthouse roof multiply by 130' for N-S and 73' for E-W story forces.

2.2 Seismic Loads



Seismic Loads

- Code Used : ASCE 7-10
- Analysis : Equivalent Lateral Force Procedure 12.8.1
- Location : Washington D.C
- Site Class : C
- $S_{DS} = 0.143$ $S_{MS} = F_a \cdot S_S = 1 \cdot 0.179$ $S_{DS} = \frac{2}{3} S_{MS} = 0.12$

  $S_{D1} = 0.071$ $S_{M1} = F_v S_1 = 1 \; 0.063$ $S_{D1} = \frac{2}{3} S_{M1} = 0.042$
- $S_S = 0,179$

  $S_1 = 0,063$
- Lateral System : Ordinary Reinforced Concrete shear walls

Base Shear $V = C_s \cdot W$ 12.8-1

Where C_s = Response Coefficient 12.8.1.1

- $C_s = \frac{S_{DS}}{R/I_e} = \frac{0.143}{4/1} = 0.03575$

- $R = 4$
- $\Omega_0 = 2.5$
- $C_d = 4$

$\Big\}$ Table 12.2-1

- $T_L = 8$ seconds figure 22-12

- $I_e = 1.0$ risk category II

- $T_a = C_t h_n^x$ Fundamental Period

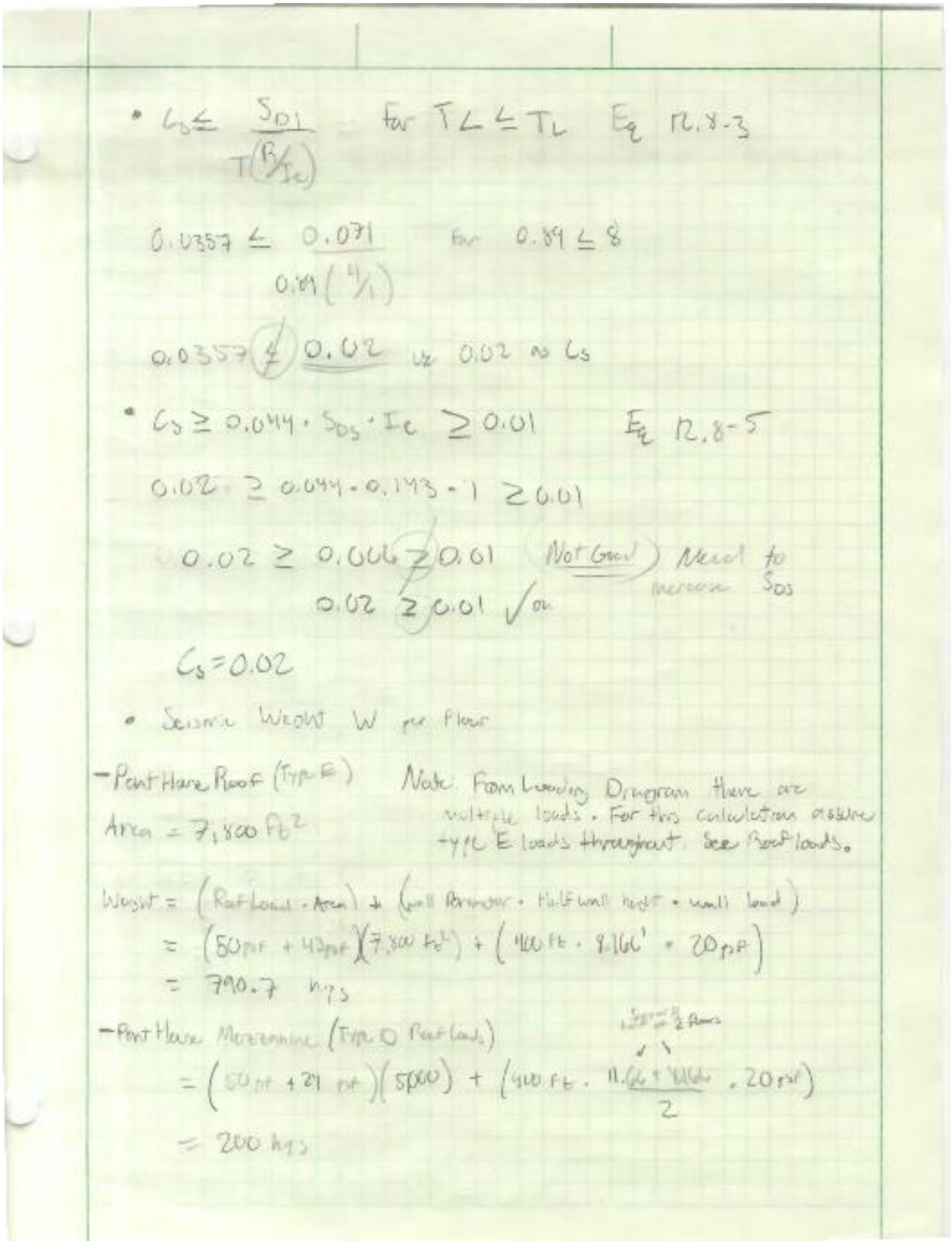
$C_t = 0.02$ table 12.8-2

$x = 0.75$ table 12.8-2

$\Big\{$ (All other Structural Systems)

$h_n = 158.5$ From Grade to Roof

$T_a = 0.02(158.5)^{0.75} = 0.89\,s$



- $C_s \leq \dfrac{S_{D1}}{T\left(\frac{R}{I_e}\right)}$ for $T \leq T_L$ Eq 12.8-3

$0.0357 \leq \dfrac{0.071}{0.89\left(\frac{4}{1}\right)}$ for $0.89 \leq 8$

$0.0357 \not\leq \underline{0.02}$ use 0.02 as C_s

- $C_s \geq 0.044 \cdot S_{DS} \cdot I_e \geq 0.01$ Eq 12.8-5

$0.02 \geq 0.044 \cdot 0.143 \cdot 1 \geq 0.01$

$0.02 \geq 0.006 \not\geq 0.01$ (Not Good) Need to increase S_{DS}

$0.02 \geq 0.01$ ✓ ok

$C_s = 0.02$

- Seismic Weight W per Floor

-Pent House Roof (Type E)

Area = 7,800 ft²

Note: From Loading Diagram there are multiple loads. For this calculation assume type E loads throughout. See Roof loads.

Weight = (Roof Load · Area) + (wall Perimeter · Half wall height · wall load)

$= (50\text{psf} + 43\text{psf})(7{,}800\ \text{ft}^2) + (400\ \text{ft} \cdot 9.166' \cdot 20\ \text{psf})$

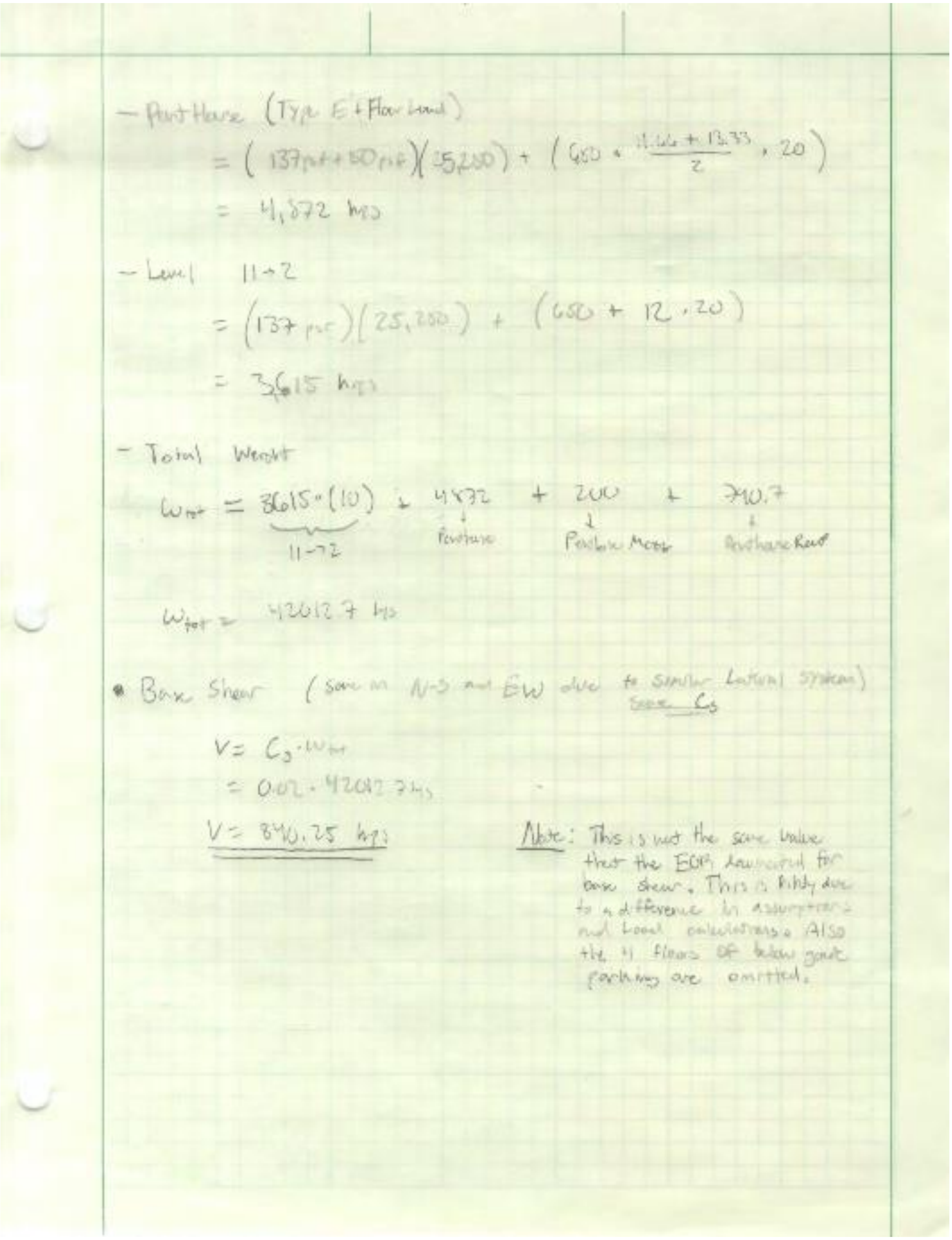
$= 790.7$ kips

-Pent House Mezzanine (Type D Roof Loads)

[illegible] 2 floors

$= (50\ \text{psf} + 29\ \text{psf})(5000) + \left(400\ \text{ft} \cdot \dfrac{11.66 + 9.166}{2} \cdot 20\ \text{psf}\right)$

$= 200$ kips



– Penthouse (Type E + Floor Load)

$$= (137\,psf + 50\,psf)(25{,}200) + \left(650 \cdot \frac{11.66 + 13.33}{2} \cdot 20\right)$$

$$= 4{,}872 \text{ kips}$$

– Level 11 → 2

$$= (137\,psf)(25{,}200) + (650 + 12 \cdot 20)$$

$$= 3{,}615 \text{ kips}$$

– Total Weight

$$W_{tot} = \underbrace{3615 \cdot (10)}_{11 \to 2} + \underset{\text{Penthouse}}{\underset{\downarrow}{4872}} + \underset{\text{Penthouse Mech}}{\underset{\downarrow}{200}} + \underset{\text{Penthouse Roof}}{\underset{\downarrow}{740.7}}$$

$$W_{tot} = 42012.7 \text{ kips}$$

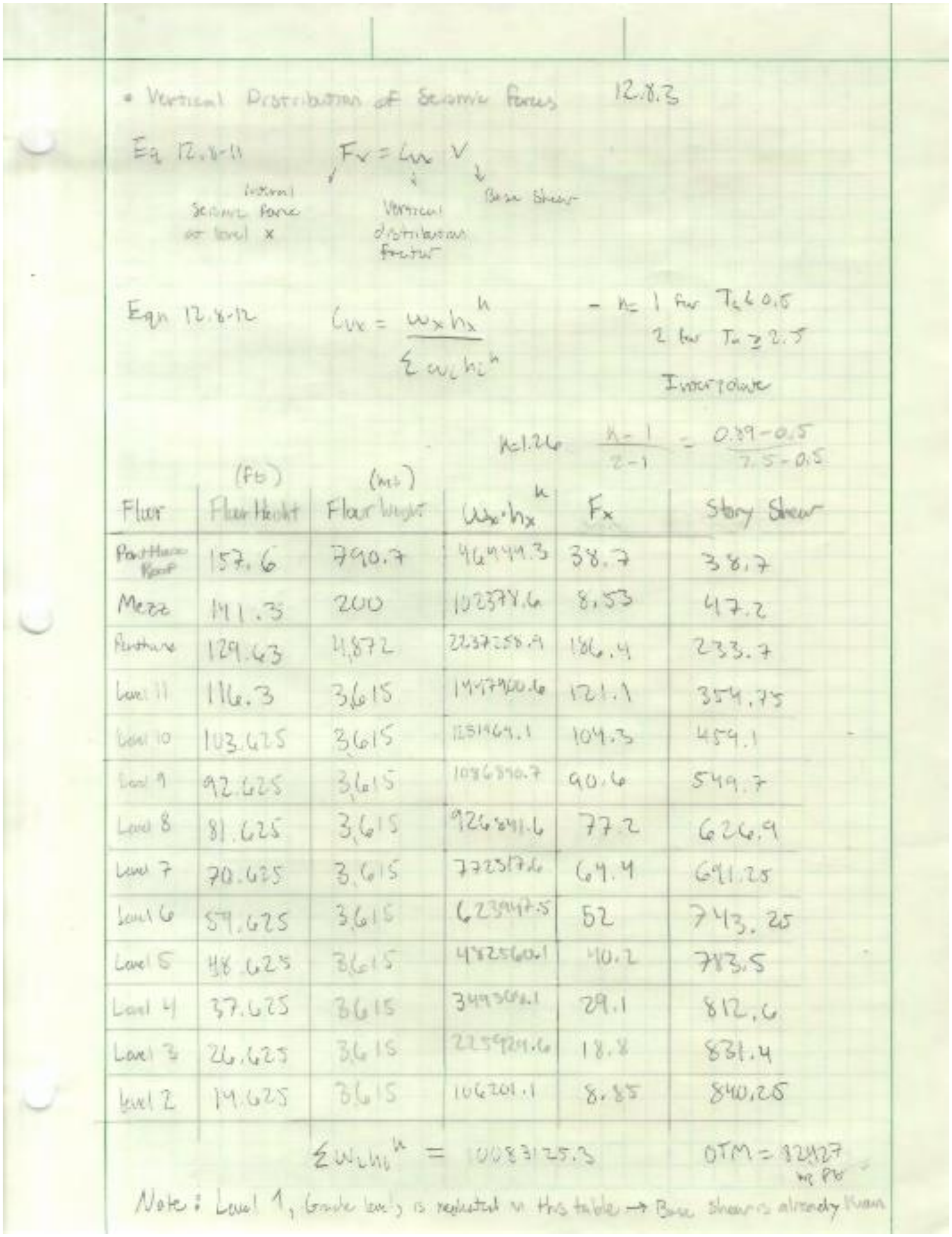
- Base Shear (same in N-S and EW due to similar Lateral system) Same C_s

$$V = C_s \cdot W_{tot}$$

$$= 0.02 \cdot 42012.7 \text{ kips}$$

$$\underline{\underline{V = 840.25 \text{ kips}}}$$

Note: This is not the same value that the EOR calculated for base shear. This is likely due to a difference in assumptions and load calculations. Also the 4 floors of below grade parking are omitted.



- Vertical Distribution of Seismic Forces 12.8.3

Eq 12.8-11 $F_x = C_{vx} V$

Lateral seismic force at level x

Vertical distribution factor

Base Shear

Eqn 12.8-12 $C_{vx} = \frac{w_x h_x^k}{\sum w_i h_i^k}$

- k = 1 for $T_a < 0.5$

2 for $T_a \geq 2.5$

Interpolate

$k = 1.26$ $\frac{k-1}{2-1} = \frac{0.89-0.5}{2.5-0.5}$

Floor	(ft) Floor Height	(kt) Floor Weight	$w_x \cdot h_x^k$	F_x	Story Shear
Penthouse Roof	157.6	790.7	46444.3	38.7	38.7
Mezz	141.3	200	102374.6	8.53	47.2
Penthouse	129.63	4,872	2237258.9	186.4	233.7
Level 11	116.3	3,615	1447960.6	121.1	354.75
Level 10	103.625	3,615	1251464.1	104.3	459.1
Level 9	92.625	3,615	1086890.7	90.6	549.7
Level 8	81.625	3,615	926841.6	77.2	626.9
Level 7	70.625	3,615	772317.6	64.4	691.25
Level 6	59.625	3,615	623947.5	52	743.25
Level 5	48.625	3,615	482560.1	40.2	783.5
Level 4	37.625	3,615	349360.1	29.1	812.6
Level 3	26.625	3,615	225924.6	18.8	831.4
Level 2	14.625	3,615	106201.1	8.85	840.25

$\sum w_i h_i^k = 10083125.3$ OTM = 82427 k-ft

Note: Level 1, Grade level, is neglected in this table → Base shear is already known

N-S / E-W Profile of Story Shears with OTM