27 September 2013

Letter of Transmittal

Department of Architectural Engineering

The Pennsylvania State University

Dr. Boothby,

This letter is to prove submittal of Technical Report 2 for the Orchard Plaza Senior Thesis project. All necessary documents are included with this submittal. Calculations supporting my claims are included in respective appendices.

Thank you for assistance with this assignment,

Christopher Duarte

TECHNICAL REPORT 2

ORCHARD PLAZA

AE SENIOR THESIS

Christopher Duarte - Structural
Advisor: Thomas Boothby
September 27th, 2013

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EXECUTIVE SUMMARY

The following report investigates various forms of gravity loads. as well as wind and seismic loads. Respective calculations were performed to analyze the building with the appropriate codes in comparison with given factors and information from the building documents. The codes listed in this document were referenced frequently when performing calculations. Drawings provided by STRADA Architects were used for all drawings with permission from the building's owner, Millcraft Investments.

SITE PLAN

Orchard Plaza is situated in an urban environment with close proximity to neighboring streets. The building is located in Pennsylvania approximately twenty miles southwest of Pittsburgh.

CODES

The following codes were used for the design of Orchard Plaza

- 2003 International Building Code
- Minimum Design Loads for Building and Other Structures (ASCE 7-02)
- Building Code Requirements for Structural Concrete (ACI 318-02)
- AISC Manual of Steel Construction, Allowable Stress Design (ASD)

GRAVITY LOADS

A complete estimate of the building's weight can be found in Appendix A

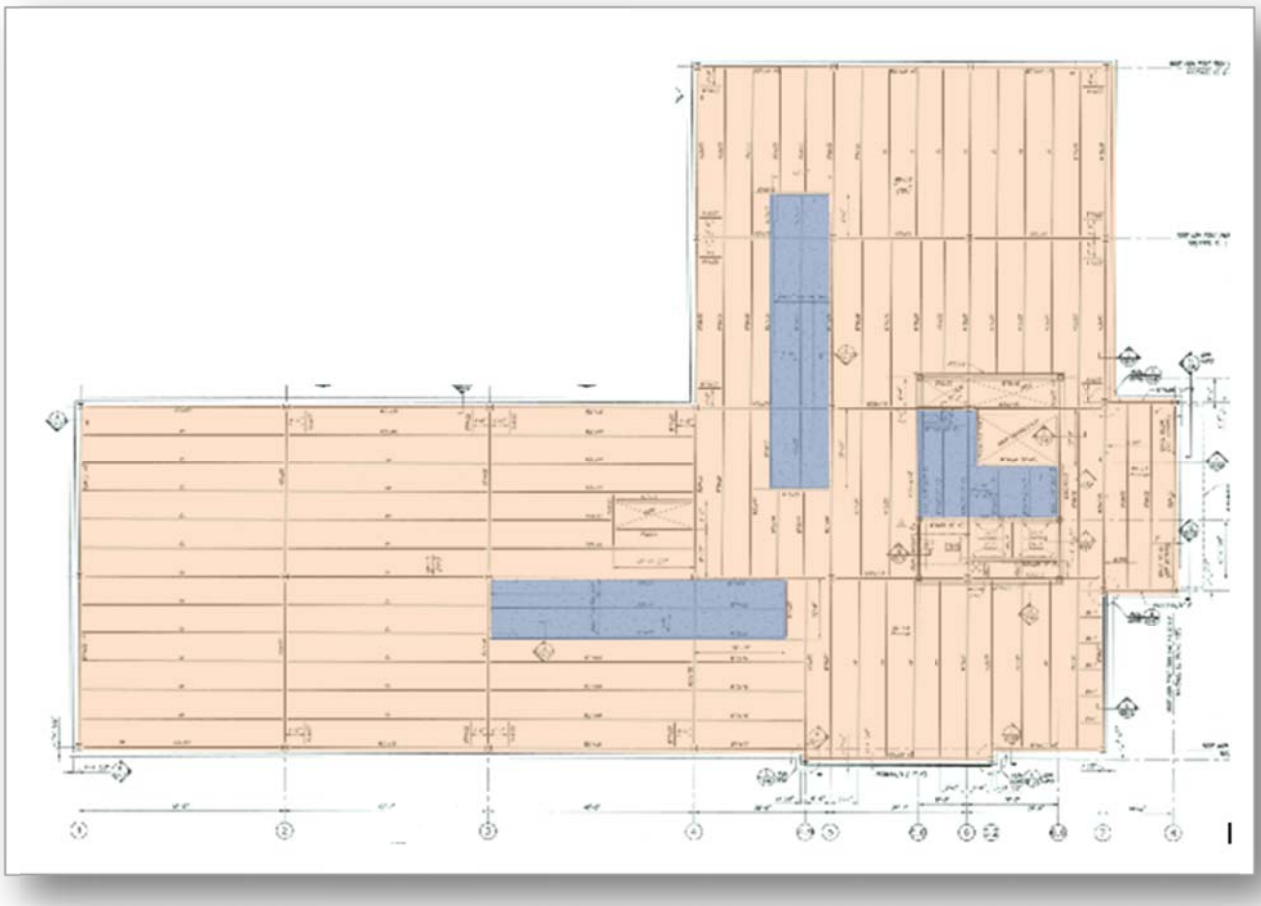
Dead Loads	
Description	**Load (psf)**
Ceiling + Misc. Mechanical	15
Roofing	11
Exterior Walls	56
Floor Slab - Level 1	72
Floor Slab - Levels 2-6	66

Live Loads	
Description	**Load (psf)**
Lobbies & Corridors	100
Office Areas	60 + 20DL
Main Corridors Above Ground Level	80
Electrical & Mechanical Rooms	200
Stairs & Landings	100
Light Storage	125
General File Areas	175
Heavy Storage	250
Roof Live Load	30

Snow Loads	
Description	**Value**
Ground Snow Load P_g	25 psf
Flat-Roof Snow Load P_f	18 psf
Snow Exposure Factor C_e	1
Snow Importance Factor I_e	1
Thermal Factor	1
Wind Directionality Factor K_d	0.85

ROOF LOADS

The roof system of Orchard Plaza is comprised of the two components shown below.

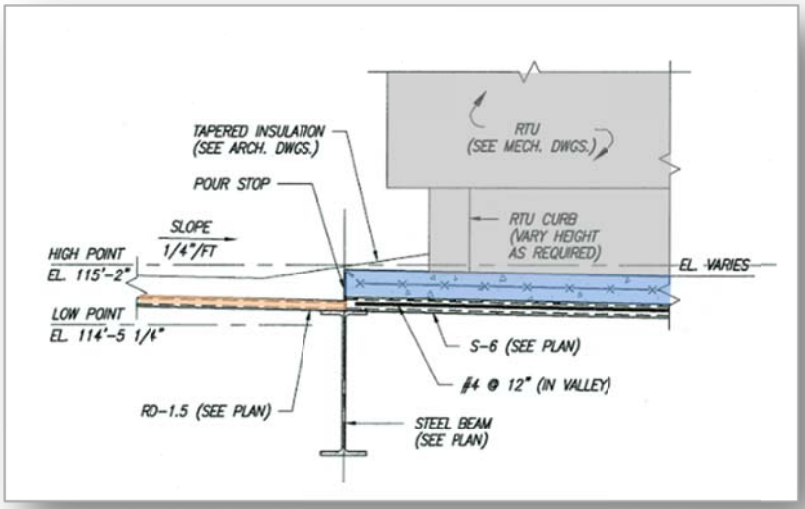


Concrete Mechanical Pad

- 4" Normal Weight Concrete
- 2"-18Gage Composite Decking
- 6x6 – W2.9 x W2.9 Welded Wire Frame

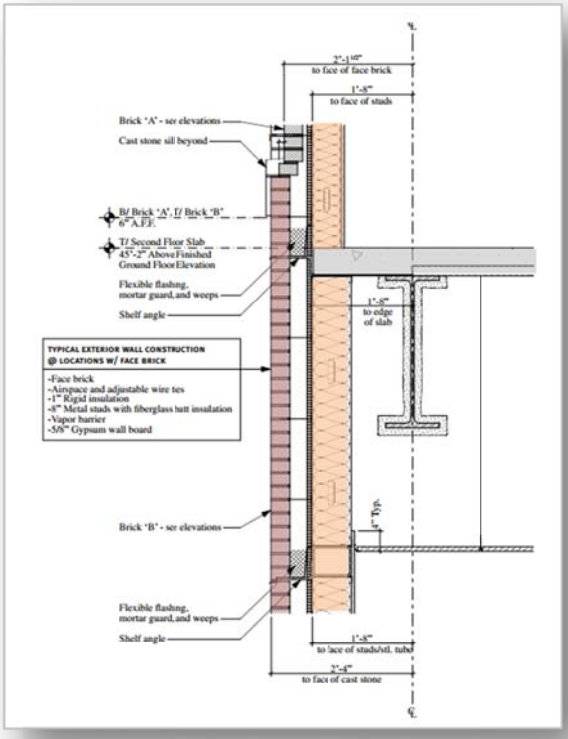
1.5B20 Roof Decking - Vulcraft

A cross section of both roofing elements is shown below.



EXTERIOR LOADS

Weight of the exterior façade was estimated using ASCE 7-02. Exterior loads are estimated to account for forty percent of the total building weight



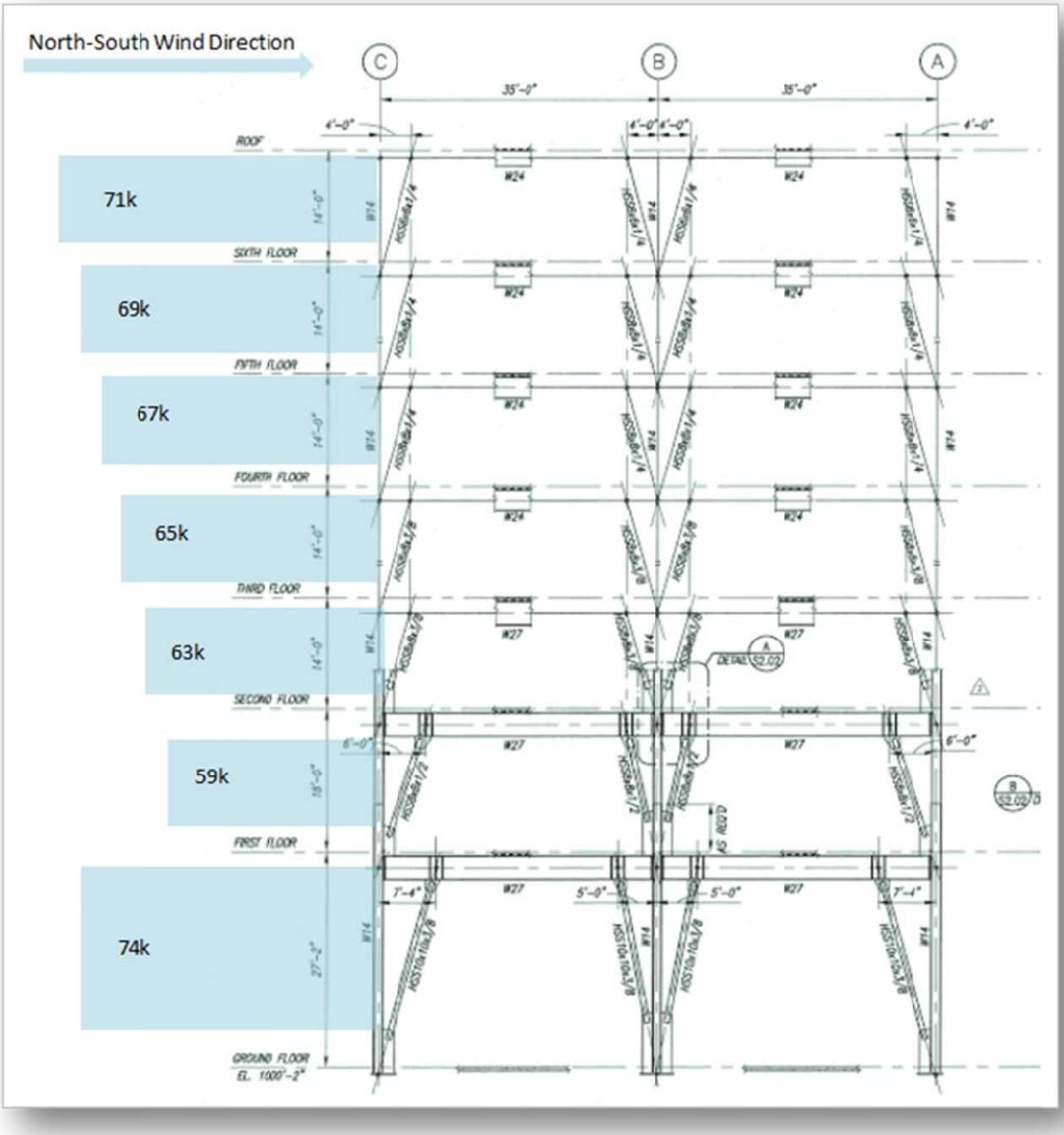
WIND LOADS

To simplify wind calculations, the building was assumed to be of a rectangular shape instead of an L-shape. This assumption proved to be effective as the largest base shear of 469k calculated is very similar to the 495k prescribed by the building documents. Calculations for wind loads can be found in Appendix B.

Wind Pressure (North-South)										
Level	z	k_z	q_h	q_z (psf)	Windward (psf)	Leeward (psf)	Trib. Area (sf)	Force (k)	Story Shear (k)	Overturning Moment (ft-k)
1	0	0.57	16.74	10.04	9.54	-9.81	3840	74	469	0
2	18	0.61	16.74	10.75	10	-9.81	2987	59	395	1065
3	32	0.71	16.74	12.51	11.15	-9.81	2987	63	335	2003
4	46	0.79	16.74	13.92	12.06	-9.81	2987	65	273	3004
5	60	0.85	16.74	14.98	12.75	-9.81	2987	67	208	4046
6	74	0.91	16.74	16.03	13.43	-9.81	2987	69	140	5136
Roof	88	0.95	16.74	16.74	13.85	-9.81	2987	71	71	6219
Base Shear (k) = 469										
Total Overturning Moment (ft-k) = 21472										

Wind Pressure (East - West)										
Level	z	k_z	q_h	q_z (psf)	Windward (psf)	Leeward (psf)	Trib. Area (sf)	Force (k)	Story Shear (k)	Overturning Moment (ft-k)
1	0	0.57	16.74	10.04	9.64	-9.92	2592	51	320	0
2	18	0.61	16.74	10.75	10.11	-9.92	2016	40	270	727
3	32	0.71	16.74	12.51	11.27	-9.92	2016	43	229	1366
4	46	0.79	16.74	13.92	12.20	-9.92	2016	45	186	2052
5	60	0.85	16.74	14.98	12.90	-9.92	2016	46	142	2760
6	74	0.91	16.74	16.03	13.60	-9.92	2016	47	96	3508
Roof	88	0.95	16.74	16.74	14.07	-9.92	2016	48	48	4259
Base Shear (k) = 320										
Total Overturning Moment (ft-k) = 14672										

Wind loads were found to be strongest along the North-South direction which has the largest surface area exposure for wind loading. Loads gradually increased up the building with the exception of the lowest level which has an atypical floor high that has a larger story height and therefore more surface area for wind loading.



SEISMIC LOADS

Seismic loads were calculated to determine whether wind or seismic loads control for this building. It was found that while seismic load base shear is very similar to wind base shear, seismic loading does not control for Orchard Plaza. Calculations for this comparison can be found in Appendix C.

Seismic Loads					
Level	**h_x (ft)**	**w_x (k)**	**c_{vx}**	**F_v (k)**	**Overturning Moment (ft-k)**
1	0	2016	0	0	0
2	18	1892	0.0691	28	509
3	32	1892	0.1283	53	1683
4	46	1892	0.1894	78	3570
5	60	1892	0.252	103	6192
6	74	1892	0.3156	130	9598
Roof	88	227	0.0456	19	1646
$\Sigma(w_i)(h_i)^k$ = 610000					
Base Shear (k) = 410					
Total Overturning Moment (ft-k) = 23198					

APPENDIX A – GRAVITY LOAD CALCULATIONS

Gravity Loads Avg Floor Area = 20580 ft²

Floor Weights ASD

First Level Deck + Concrete = 63 psf – 2VLI18 Vulcraft

Level 2-6 Deck + Concrete = 57 psf – 2VLI18 Vulcraft

Steel Beams (typical)

$28'/_{3\ spaces} = 9.33'$

$35'/_{4\ spaces} = 8.75'$ ← controls

W21×44 @ 8.75′ $44\ plf/_{8.75'} = 5.03\ psf$

Steel Girders (typical)

42′ spacing

W30×99 $99\ plf/_{42'} = 2.36\ psf$

Exterior Wall

Total Surface Area (approximate)

$(213.33')(88')(2) + (144')(88') + (144')(88 - 18') = 60300\ ft^2$

Assume exterior = 40% bldg weight

$60300\ ft^2\ (0.4)(56\ psf) = 1350.7\ K$

$\frac{1350.7\ K}{6\ levels} = 225.1\ K/level$

Steel Columns (typical)

W14×159 as average $\frac{(heaviest\ level\ 1 + heaviest\ level\ 6)}{2}$

Avg 14 columns/level $\frac{(257\ plf + 61\ plf)}{2} = 159\ plf$

$159 \times 14'\ story\ (typ) \times 14 = \frac{31164\ lb}{Floor\ Area} = \frac{31164\ lb}{20580\ sf} = 1.51\ psf$

APPENDIX A – GRAVITY LOAD CALCULATIONS

Gravity Loads

Floor Self Weights ASD

First Floor Self weight = 63 + 5.03 + 2.36 + 1.51 = 72 psf

Floor 2-6 Self weight = 57 + 5.03 + 2.36 + 1.51 = 66 psf

Roof

Concrete Pad Area

$2(60.83')(12.75')(4\text{" thick}) + (23')(29')(4\text{" thick}) = 481 \text{ cf conc.}$

$481 \text{ cf } (150 \text{ lb/cf}) = \frac{72129 \text{ lb}}{20580 \text{ sf}} = 3.5 \text{ psf}$

1.5B20 Gage – Vulcraft = 2.14 psf ⟶ 2.5 psf per ASCE

Roof Total = 2.5 psf + 3.5 psf + 1 psf + 4 psf = 11 psf

1 psf = Acoustic ceiling
4 psf = Mechanical Duct
} ASCE 7-02 Table C3-1

Floor Total Weights

Level 1 = 72 psf + 1 psf + 4 psf + 10 psf = 87 psf

10 psf = misc. loads

(87 psf)(20580 sf) + 225.1 K (exterior wall / level) = 2016 K

Levels 2-6 = 66 psf + 1 psf + 4 psf + 10 psf = 81 psf

(81 psf)(20580 sf) + 225.1 K = 1892 K

Roof = 11 psf (20580 sf) = 227 K

Total Building Weight

227K + 2016 + 1892(5) = 11703 K

APPENDIX B – WIND LOAD CALCULATIONS

Wind Loads ASCE 7-02

Basic Wind Speed = 90 mph — $K_d = 0.85$

Importance Factor = $I_w = 1.0$ — $K_{zt} = 1.0$

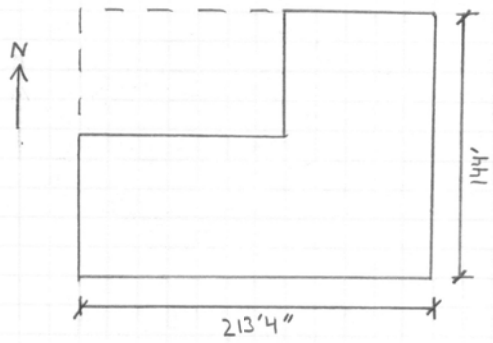
Building Category II — $h = 88'$

Exposure Category B — $B = 213.33$ ft

Internal Pressure $GC_{pi} = \pm 0.18$ — $L = 144$ ft

$g_Q = g_v = 3.4$ §6.5.8.1

Rigid Structure



Consider building as if it were perfectly rectangular

Values from Table 6-2

$z_g = 1200$ $\alpha = 7$ $\ell = 320$

$z_{min} = 30$ ft $c = 0.3$ $\bar{\epsilon} = 0.33$

$\bar{z} = 0.6(88\text{ft}) = 52.8 > 30$ ✓ok

$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.3\left(\frac{33}{52.8}\right)^{1/6} = 0.277$

$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 320\left(\frac{52.8}{33}\right)^{0.33} = 374.3$

APPENDIX B – WIND LOAD CALCULATIONS

Wind Loads Cont.

North – South

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}} = \sqrt{\frac{1}{1 + 0.63\left(\frac{213.33 + 88}{374.3}\right)}} = 0.803$$

East – West

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{144 + 88}{374.3}\right)}} = 0.825$$

Gust Factor

North – South

$$G = 0.925\left(\frac{1 + 1.7 g_Q I_{\bar{z}} Q}{1 + 1.7 g_v I_{\bar{z}}}\right) = 0.925\left(\frac{1 + 1.7(3.4)(0.277)(0.803)}{1 + 1.7(3.4)(0.277)}\right)$$

$$G = 0.8128$$

East – West

$$G = 0.925\left(\frac{1 + 1.7(3.4)(0.277)(0.825)}{1 + 1.7(3.4)(0.277)}\right)$$

$$G = 0.8254$$

$$K_z = \begin{cases} 2.01\left(\frac{z}{z_g}\right)^{2/\alpha} & 15' < z < z_g \\ 2.01\left(\frac{15}{z_g}\right)^{2/\alpha} & z < 15' \end{cases}$$

$$q_h = 0.00256\, K_z\, K_{zt}\, K_d\, V^2 I_w$$

$$q_h = 0.00256(0.95)(1)(0.85)(90^2)(1)$$

$$q_h = 16.74 \text{ psf}$$

APPENDIX B – WIND LOAD CALCULATIONS

Wind Loads Cont.

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

WW $C_p = 0.8$ Table 6-6

LW $C_p = -0.5$ Table 6-6

North - South

Windward

$$P_{WW} = q_z(0.8128)(0.8) - q_i(-0.18)$$

Leeward

$$P_{LW} = q_z(0.8128)(-0.5) - q_i(0.18)$$

East - West

Windward

$$P_{WW} = q_z(0.8254)(0.8) - q_i(-0.18)$$

Leeward

$$P_{LW} = q_z(0.8254)(-0.5) - q_i(0.18)$$

APPENDIX C – SEISMIC LOAD CALCULATIONS

Seismic Loads ASCE 7-02

Site Class C — Response Modification Factor $R = 3$

Importance Factor $I_e = 1.0$ — Design Base Shear $V = 495K$

Building Category II — Seismic Response Coefficient $C_s = .035$

Following Values are from geohazards.usgs.gov/designmaps/us 2002 USGS Hazard Data

$S_s = 0.124_g$ $S_{MS} = 0.149_g$

$S_1 = 0.05_g$ $S_{M1} = 0.084_g$

Following Values From Documents S4.01

$S_{DS} = 0.104_g$

$S_{D1} = 0.068_g$

Fundamental Period

$$C_s = \frac{S_{D1}}{T(R/I)} \qquad T = \frac{S_{D1}}{C_s(R/I)} = \frac{.068}{.035\left(\frac{3}{1}\right)} = 0.648_{sec}$$

Vertical Distribution of Forces

	T	K
	0.5	1
Interpolate	0.648	1.074
	2.5	2

C_{vx} at Roof

$$\frac{227(88)^{1.074}}{227(88)^{1.074} + 1892(74)^{1.074} + 1892(60)^{1.074} + 1892(46)^{1.074} + 1892(32)^{1.074} + 1892(18)^{1.074}}$$

$\Sigma w_i h_i^k = 610000$

C_{vx} at roof $= 0.0456$

Check

$\Sigma C_{vx} = 1$ ✓ OK

APPENDIX C – SEISMIC LOAD CALCULATIONS

Seismic Loads

Total Building Weight = 11703 K (building weight calculation)

$V = C_s W$ $\quad C_s = 0.035$ (given)

$V = 0.035(11703) = 409.6$ K

F_v at Roof

$F_v = C_{vx} V = 0.0456\ (409.6) = 18.7$

All othe C_{vx} and F_v in spread sheet

Check

$\Sigma F_v = 409.6$ K ✓ OK

APPENDIX C – SEISMIC LOAD CALCULATIONS

USGS Design Maps Summary Report

Print View Detailed Report

User-Specified Input

Building Code Reference Document	2003 NEHRP Recommended Seismic Provisions (which utilizes USGS hazard data available in 2002)
Site Coordinates	40.17045°N, 80.25209°W
Site Soil Classification	Site Class C – "Very Dense Soil and Soft Rock"
Seismic Use Group	I/II

USGS-Provided Output

S_s =	0.124 g	S_{MS} =	0.149 g	S_{DS} =	0.100 g
S_1 =	0.050 g	S_{M1} =	0.084 g	S_{D1} =	0.056 g

Design Response Spectrum