Appendix

Appendix A: Snow Load Analysis

Cody Scheller | Senior Thesis | Snow Analysis | 1

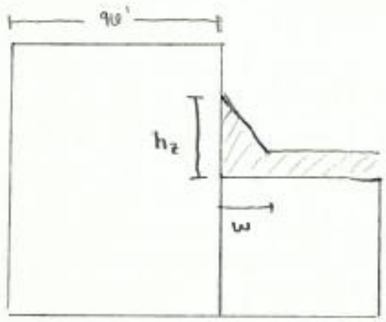
7.3 → Flat Roof Snow Load

$P_f = 0.7\, C_e C_t I_s P_g$

→ where
$C_e = 0.9$
$C_t = 0.1$
$I_s = 1.1$
$P_g = 25$

$P_f = (0.7)(0.9)(1.0)(1.1)(25) = \boxed{17.325\ \text{lb/ft}^2}$

→ Snow Drift



$h_z = 0.43\sqrt[3]{l_u}\,\sqrt[4]{P_g+10} - 1.5$

$= 0.43\sqrt[3]{96}\,\sqrt[4]{25+10} - 1.5$

$= 3.29'$

$w = 4h_z = 13.2'$

$P_z = h_z \gamma$

$\gamma = 0.13 P_g + 3$

$\gamma = 0.13(25) + 3 = 6.25$

Drift $= P_d = 3.29(6.25)$

$= \boxed{20.56\ \text{lb/ft}^2}$

Appendix B: Wind Load Analysis

Cody Scheller | Senior Thesis | Wind Analysis | 1

Wind Design

→ Use ASCE 7-10 – MWFRS (Directional Procedure)

27.2.1

→ Basic Wind Speed (26.5)

→ Occupancy Category III (Table 1.5-1)

↳ wind speed: V = 120 mph

→ Wind Directionality Factor (K_d) = 0.85

→ Exposure Factor → B

→ Topographic Factor (K_{zt}) → 1.0

→ Gust-Effect Factor (26.9) → Rigid?

→ Approximate Natural Frequency Limitations

1.) Building Height = 97' < 300' ∴ ok ✓

2.) Building Height = 97' < 4 L_{eff}

→ Check N-S Direction

$$L_{eff} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} = 208' \rightarrow 4(208) > 97' \text{ ok} ✓$$

→ Check E-W Direction

$$L_{eff} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} = 97' \rightarrow 4(97) > 97' \text{ ok} ✓$$

∴ Can Approximate

Appendix B: Wind Load Analysis

Cody Scheller | Senior Thesis | Wind Analysis | 2

Wind Design

26.9.3

→ Concrete Moment-resisting Frame Building

$$n_a = \frac{385 c_w^{0.5}}{h} = \frac{385\,(0.006)^{0.5}}{97} = 0.31 < 1.0$$

∴ Flexible

26.9.5

→ Flexible Building

$$G_f = 0.925\left[\frac{1 + 1.7 I_{\bar{z}} \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1 + 1.7 g_v I_{\bar{z}}}\right] = 1.24$$

$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.30\left(\frac{33}{58.2}\right)^{1/6} = 0.27$$

$c = 0.30$

$\bar{z} = \max \begin{cases} 0.6h = 0.6(97) = 58.2 \\ z_{min} = 14 \end{cases}$

$g_Q = g_v = 3.4$

$$g_R = \sqrt{2\ln(3600 n_1)} + \frac{0.577}{\sqrt{2\ln(3600 n_1)}} = 3.79$$

$n_1 = n_a = 0.31$

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (0.53 + 0.47 R_L)} = 1.21$$

$$R_n = \frac{7.47 N_1}{(1+10.3 N_1)^{5/3}} = \frac{7.47(0.984)}{[1+10.3(0.984)]^{5/3}} = 0.132$$

$$N_1 = \frac{n_1 L_{\bar{z}}}{V_{\bar{z}}} = \frac{0.31(251.30)}{79.2} = 0.984$$

Appendix B: Wind Load Analysis

Cody Scheller | Senior Thesis | Wind Analysis | 3

$$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 208\left(\frac{58.2}{33}\right)^{1/3} = 251.30$$

$$V_{\bar{z}} = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}}\left(\frac{88}{60}\right)V = 0.45\left(\frac{58.2}{33}\right)^{1/4}\left(\frac{88}{60}\right)120 = 79.2$$

R_h:

$$\eta = \frac{4.6 n_1 h}{\bar{V}_z} = \frac{4.6(0.31)(97)}{79.2} = 1.75$$

$$R_h = \frac{1}{\eta} - \frac{1}{2\eta^2}\left(1 - e^{-2\eta}\right) = 0.413$$

R_B:

$$\eta = \frac{4.6 n_1 B}{V_{\bar{z}}} = \frac{4.6(0.3)(96)}{79.2} = 1.67$$

$$R_B = \frac{1}{\eta} - \frac{1}{2\eta^2}\left(1 - e^{-2\eta}\right) = 0.423$$

R_L:

$$\eta = \frac{4.6 n_1 L}{V_{\bar{z}}} = \frac{4.6(0.31)(208)}{79.2} = 3.75$$

$$R_L = \frac{1}{\eta} - \frac{1}{2\eta_2}\left(1 - e^{-2\eta}\right) = 0.231$$

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}} = 0.81$$

Assume $\beta = 0.01 \rightarrow$ 1% damping for concrete structure

Appendix B: Wind Load Analysis

→ Enclosure Classification (26.10)

↳ ENCLOSED

→ Internal Pressure Coefficient = ±0.18

→ Wall Pressure Coefficients, C_p

→ Wind in N/S Direction

→ Windward Wall: $C_p = 0.8$

→ Leeward Wall: $(L/B) = 0.46$ $C_p = -0.5$

→ Wind in E/W Direction

→ Windward Wall: $C_p = 0.8$

→ Leeward wall: $(L/B) = 2.17$ → $C_p = -0.3$

→ Vertical Pressure

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

$q_z = (0.00256)(K_z)(1.0)(0.85)(120)^2$

$q_z = 31.33 K_z$

→ Design Pressures

→ Windward (N/S & E/W)

→ $p = G_F C_p q_z = (1.24)(0.8) q_z - q_h(\pm 0.18)$

→ Leeward (N/S)

→ $p = G_F C_p q_h = (1.24)(-0.5) q_h - q_h(\pm 0.18)$

→ Leeward (E/W)

→ $p = G_F C_p q_h = (1.24)(-0.3) q_h - (q_h)(\pm 0.18)$

Appendix B: Wind Load Analysis

North-South Direction - Case #1										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward N-S	Leeward N-S	Total N-S			
Roof	97	14	0.981	30.73	36.01	-24.58	60.60	81.44	0.00	0.00
7	83	14	0.939	29.42	34.71	-24.58	59.30	79.70	81.44	7899.88
6	69	14	0.886	27.76	33.07	-24.58	57.65	77.48	161.14	6614.73
5	55	14	0.830	26.00	31.32	-24.58	55.90	75.14	238.62	5346.28
4	41	14	0.765	23.97	29.31	-24.58	53.89	72.43	313.76	4132.47
3	27	14	0.676	21.18	26.54	-24.58	51.12	68.71	386.18	2969.60
2	13	14	0.570	17.86	23.25	-24.58	47.83	64.28	454.89	1855.16
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	519.18	835.68
								Total	**519.18**	**29653.79**

East-West Direction - Case #1										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward E-W	Leeward E-W	Total E-W			
Roof	97	14	0.981	30.73	36.01	-16.96	52.98	154.27	0.00	0.00
7	83	14	0.939	29.42	34.71	-16.96	51.68	150.48	154.27	14963.73
6	69	14	0.886	27.76	33.07	-16.96	50.03	145.69	304.75	12489.93
5	55	14	0.830	26.00	31.32	-16.96	48.28	140.60	450.43	10052.32
4	41	14	0.765	23.97	29.31	-16.96	46.27	134.74	591.03	7733.09
3	27	14	0.676	21.18	26.54	-16.96	43.50	126.68	725.77	5524.24
2	13	14	0.570	17.86	23.25	-16.96	40.21	117.09	852.45	3420.31
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	969.54	1522.14
								Total	**969.54**	**55705.78**

Appendix B: Wind Load Analysis

North-South Direction - Case #2										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward N-S	Leeward N-S	Total N-S			
Roof	97	14	0.981	30.73	36.01	-24.58	60.60	61.08	0.00	879.57
7	83	14	0.939	29.42	34.71	-24.58	59.30	59.77	61.08	860.71
6	69	14	0.886	27.76	33.07	-24.58	57.65	58.11	120.85	836.81
5	55	14	0.830	26.00	31.32	-24.58	55.90	56.35	178.96	811.47
4	41	14	0.765	23.97	29.31	-24.58	53.89	54.32	235.32	782.24
3	27	14	0.676	21.18	26.54	-24.58	51.12	51.53	289.64	742.06
2	13	14	0.570	17.86	23.25	-24.58	47.83	48.21	341.17	694.26
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	389.38	0.00
								Total	**389.38**	**4727.54**

East-West Direction - Case #2										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward E-W	Leeward E-W	Total E-W			
Roof	97	14	0.981	30.73	36.01	-16.96	52.98	115.70	0.00	2406.54
7	83	14	0.939	29.42	34.71	-16.96	51.68	112.86	115.70	2347.51
6	69	14	0.886	27.76	33.07	-16.96	50.03	109.26	228.56	2272.70
5	55	14	0.830	26.00	31.32	-16.96	48.28	105.45	337.82	2193.39
4	41	14	0.765	23.97	29.31	-16.96	46.27	101.05	443.28	2101.91
3	27	14	0.676	21.18	26.54	-16.96	43.50	95.01	544.33	1976.18
2	13	14	0.570	17.86	23.25	-16.96	40.21	87.82	639.34	1826.57
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	727.15	1141.60
								Total	**727.15**	**13859.85**

Appendix B: Wind Load Analysis

North-South Direction - Case #3										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward N-S	Leeward N-S	Total N-S			
Roof	97	14	0.981	30.73	36.01	-24.58	60.60	61.08	0.00	0.00
7	83	14	0.939	29.42	34.71	-24.58	59.30	59.77	61.08	5924.91
6	69	14	0.886	27.76	33.07	-24.58	57.65	58.11	120.85	4961.04
5	55	14	0.830	26.00	31.32	-24.58	55.90	56.35	178.96	4009.71
4	41	14	0.765	23.97	29.31	-24.58	53.89	54.32	235.32	3099.35
3	27	14	0.676	21.18	26.54	-24.58	51.12	51.53	289.64	2227.20
2	13	14	0.570	17.86	23.25	-24.58	47.83	48.21	341.17	1391.37
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	389.38	626.76
								Total	**389.38**	**22240.34**

East-West Direction - Case #3										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward E-W	Leeward E-W	Total E-W			
Roof	97	14	0.981	30.73	36.01	-16.96	52.98	115.70	0.00	0.00
7	83	14	0.939	29.42	34.71	-16.96	51.68	112.86	115.70	11222.80
6	69	14	0.886	27.76	33.07	-16.96	50.03	109.26	228.56	9367.45
5	55	14	0.830	26.00	31.32	-16.96	48.28	105.45	337.82	7539.24
4	41	14	0.765	23.97	29.31	-16.96	46.27	101.05	443.28	5799.82
3	27	14	0.676	21.18	26.54	-16.96	43.50	95.01	544.33	4143.18
2	13	14	0.570	17.86	23.25	-16.96	40.21	87.82	639.34	2565.23
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	727.15	1141.60
								Total	**727.15**	**41779.33**

Appendix B: Wind Load Analysis

North-South Direction - Case #4										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward N-S	Leeward N-S	Total N-S			
Roof	97	14	0.981	30.73	36.01	-24.58	60.60	45.85	0.00	660.27
7	83	14	0.939	29.42	34.71	-24.58	59.30	44.87	45.85	646.11
6	69	14	0.886	27.76	33.07	-24.58	57.65	43.62	90.72	628.16
5	55	14	0.830	26.00	31.32	-24.58	55.90	42.30	134.34	609.14
4	41	14	0.765	23.97	29.31	-24.58	53.89	40.78	176.64	587.20
3	27	14	0.676	21.18	26.54	-24.58	51.12	38.68	217.42	557.04
2	13	14	0.570	17.86	23.25	-24.58	47.83	36.19	256.11	521.16
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	292.30	0.00
								Total	**389.38**	**3548.81**

East-West Direction - Case #4										
Floor	Height (ft)	Story Height (ft)	K_z	q_z	Wind Pressures (psf)			Story Force (kips)	Story Shear (kips)	Overturning Moment (kips-ft)
					Windward E-W	Leeward E-W	Total E-W			
Roof	97	14	0.981	30.73	36.01	-16.96	52.98	86.85	0.00	1806.51
7	83	14	0.939	29.42	34.71	-16.96	51.68	84.72	86.85	1762.19
6	69	14	0.886	27.76	33.07	-16.96	50.03	82.02	171.57	1706.04
5	55	14	0.830	26.00	31.32	-16.96	48.28	79.16	253.59	1646.50
4	41	14	0.765	23.97	29.31	-16.96	46.27	75.86	332.75	1577.83
3	27	14	0.676	21.18	26.54	-16.96	43.50	71.32	408.61	1483.45
2	13	14	0.570	17.86	23.25	-16.96	40.21	65.92	479.93	1371.14
1	0	13	0.000	0.00	0.00	0.00	0.00	0.00	545.85	856.96
								Total	**727.15**	**10404.13**

Appendix C: Seismic Load Analysis

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ASCE/SEI 7-10

11.4.2 → Site Class

D → As per geotechnical report

11.4.3 → Spectral Response Acceleration

$S_S = 0.35$

$S_1 = 0.08$

Fa:	$S_S \le 0.25$	0.35	$S_S = 0.5$
D	1.6	1.52	1.4

Fv: $S_1 \le 0.1$ then $F_v = 2.4$

$S_{MS} = F_a S_s = 1.52(0.35) = 0.532$

$S_{M1} = F_v S_1 = (2.4)(0.08) = 0.192$

11.4.4 → Design Spectral Response Acceleration

$S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3}(0.532) = 0.355$

$S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3}(0.192) = 0.128$

→ Seismic Design Category C

→ Occupancy III

12.8 → Equivalent Lateral Force Procedure

12.8.1 → Seismic Base Shear

$V = C_s W$

$W = 26{,}003.68^k$

Appendix C: Seismic Load Analysis

12.8.1.1 → Seismic Response Coefficient

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I_e}\right)}$$

$R = 6.0$ → Table 12.2-1

$I_e = 1.25$ → Table 1.5-2, III

$$C_s = \frac{0.355}{\left(\frac{6}{1.25}\right)} \rightarrow C_s = 0.0739$$

→ C_s shall not exceed:

T = Fundamental Period → 12.8.2

$$C_s = \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} \quad \text{For } T \leq T_L$$

$$C_s = \frac{S_{D1} T_L}{T^2\left(\frac{R}{I_e}\right)} \quad \text{For } T > T_L$$

T_L = Long-Period transition Period → 11.4.5

$T_L = 6$

12.8.2 → Period Determination

$$T = \min \begin{cases} C_u T_a \\ T_b \rightarrow \text{determined later from model} \end{cases}$$

$C_u = 1.7$

$T_a = C_t h_n^x$

$C_t = 0.02 \quad x = 0.75$

$T_a = 0.02(97)^{0.75}$

$h_n = 97$ ft

$T_a = 0.618$

$T = C_u T_a = 1.7(0.618) = 1.05$ s

$$C_s = \min \begin{cases} \frac{S_{DS}}{R/I_e} = \frac{0.355}{6/1.25} = 0.0739 \\ \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} = \frac{0.128}{(1.05)(6/1.25)} = \boxed{0.025} \\ \frac{S_{D1} T_L}{T^2\left(R/I_e\right)} = 0.145 \end{cases}$$

→ controls.

Appendix C: Seismic Load Analysis

Cody Scheller | Senior Thesis | Seismic Analysis | 3

$V = C_s W = (0.025)(26{,}003.68k) = \boxed{650.1k}$

12.8.3 → Vertical Distribution of Seismic Forces

$F_x = C_{vx} V$

$C_{vx} = \dfrac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$

	x_1	x	x_2
T	0.5	1.05	2.5
K	1	1.275	2

$k = 1.275$

Appendix C: Seismic Load Analysis

Seismic Parameters			
Occupancy	III	Design Short Spectral Response	0.355
Site Class	D	Design Spectral Response	0.128
Seismic Design Category	C	Maximum Short Period Spectral Response	0.532
Effective Period	1.05	Maximum Spectral Response	0.192
Seismic Response Coefficient	0.025	Short Period Spectral Response	35% g
Response Modification Coefficient	6	Spectral Response	8 % g

Seismic Analysis: Base Shear and Overturning Moment Distribution									
Floor	Height h_x (ft)	Story Height (ft)	Story Weight w_x (lbs)	h_x^k	$w_x * h_x^k$	C_{vx}	Lateral Force F_x (kips)	Story Shear V_x (kips)	Moment M_x (kips-ft)
Roof	97	14	3342.40	341.30	1140755.01	0.29	187.46	0.00	0.00
7	83	14	3205.87	279.79	896954.63	0.23	147.40	187.46	18183.87
6	69	14	3205.87	221.07	708726.22	0.18	116.47	334.86	12234.06
5	55	14	3205.87	165.56	530772.41	0.13	87.22	451.33	8036.18
4	41	14	3279.37	113.84	373327.38	0.09	61.35	538.55	4797.26
3	27	14	3279.37	66.83	219169.05	0.06	36.02	599.90	2515.33
2	13	13	3279.37	26.32	86311.41	0.02	14.18	635.92	972.45
1	0	0	3205.58	0.00	0.00	0.00	0.00	650.10	184.39
$\sum w_x h_x^k$ = 3,956,016.09			$\sum F_x$ = Base Shear = 650.10 kips			Overturning Moment = 46,923.54 kip-ft			

Appendix C: Seismic Load Analysis

Slab Weights				
Floor	Area (ft^2)	Perimeter (ft)	Weight of Concrete Slab (psf)	Total Slab Weight (kips)
1	19968	692	112.5	2246.4
2	19968	692	112.5	2246.4
3	19968	692	112.5	2246.4
4	19968	692	112.5	2246.4
5	19968	692	112.5	2246.4
6	19968	692	112.5	2246.4
7	19968	692	112.5	2246.4
Roof	19968	692	150	2995.2
		Total Slab Weight =		18720

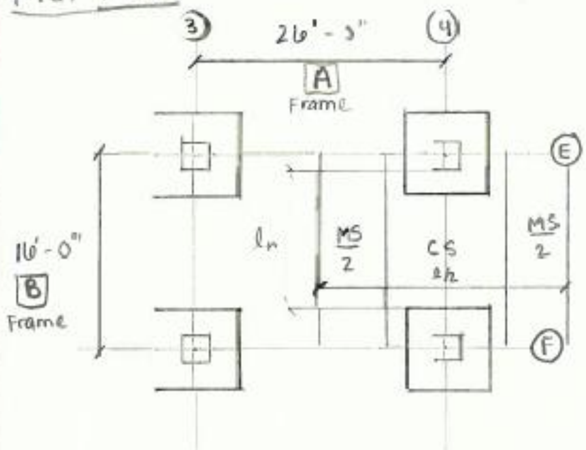
Column Weights				
Column	Number of Columns	Length (ft)	w_c (pcf)	Total Weight (kips)
16" x 16"	33	13	150.00	114.40
16" x 16"	309	14	150.00	1153.60
20" x 20"	35	13	150.00	189.58
20" x 20"	105	14	150.00	612.50
Total	482	Total Column Weight =		2070.08

Shear Wall Weights					
Length (ft)	Number of Shear Walls	Height (ft)	Thickness (in)	w_c (pcf)	Total Weight (kips)
16	6	13	16	150	249.60
16	40	14	16	150	1792.00
26	6	13	16	150	405.60
26	38	14	16	150	2766.40
Total	90	Total Shear Wall Weight =			5213.60

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 1

Flat Plate



→ Utilize 26'-0" x 16'-0" Bays

Assume 16" x 16" columns

Short Span → Frame B

$l_n = 16' - 2\left(\frac{16}{2 \cdot 12}\right) = 14.7'$

Long Span → Frame A

$l_n = 26' - 2\left(\frac{16}{2 \cdot 12}\right) = 24.7'$

Determine Slab Thickness

→ Slab without interior beams

ACI 9.5.3.2:

$$t = \begin{cases} 4\text{ in} \\ \text{Int.} = \frac{l_n}{33} = \frac{24.7'(12\text{in}/\text{ft})}{33} = 8.9\text{in} \\ \text{Ext.} = \frac{l_n}{33} = \frac{24.7'(12\text{in}/\text{ft})}{33} = 8.9\text{in} \end{cases}$$

→ use 9" slab

→ Use Equivalent Frame Method

Good for columns as low as 16" x 16"

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 2

Factored Design Loads

→ Slab Dead Load = $\frac{9''}{12}(150) = 112.5$ psf

→ $1.2w_d = 1.2(112.5+30) = 171$ psf

→ $1.6w_\ell = 1.6(80) = 128$ psf

→ $w_u = 1.2w_d + 1.6w_\ell = 299$ psf

Total Factored Static Moment

→ Frame A (16" x 16" Columns)

$M_o = \frac{1}{8} w_u \ell_2 \ell_n^2$ $\ell_n = 24.7'$

$M_o = \frac{1}{8}(299)(16')(24.7')^2/1000 = 364.83^{1\text{-}k}$

↳ Longitudinal Distribution of M_o

$M^- = 0.65 M_o = -237.14^{1\text{-}k}$

$M^+ = 0.35 M_o = +127.69^{1\text{-}k}$

→ Frame B (16" x 16" columns)

$M_o = \frac{1}{8} w_u \ell_2 \ell_n^2$ $\ell_n = 14.7'$

$M_o = \frac{1}{8}(299)(26')(14.7')^2/1000 = 210.0^{1\text{-}k}$

↳ Longitudinal Distribution of M_o

$M^- = 0.65 M_o = -136.5^{1\text{-}k}$

$M^+ = 0.35 M_o = +73.5^{1\text{-}k}$

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 3

Interior Tranverse Distribution %'s

Item/Description	Frame A	Frame B
1.) Total Tranverse Width	312"	192"
2.) Column Strip Width	96"	96"
3.) Middle Strip Width	216"	96"
4.) Torsional Constant ↳ no beams → C = 0	0	0
5.) $I_S = \ell t^3/12 = (192")(9)^3/12$	11,664	11,664
6.) $B_t = C/2I_S = 0$	0	0
7.) $\alpha_1 = I_b/I_s$	0	0
8.) ℓ_2/ℓ_1 = aspect ratio	$\frac{312}{192} = 1.625$	$\frac{192}{312} = 0.62$
9.) $\alpha_1 \ell_2 \ell_1 = 0$	0	0
10.) M^+ % to C.S.	60%	60%
11.) M^- % to C.S.	75%	75%

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 4

Frame A

	M^- (1-k)	M^+ (1-k)
Total Moment	-237.14^{1-k}	$+127.69^{1-k}$
% to C.S.	75%	60%
Moment in C.S.	-177.86	+76.61
Moment in M.S.	-59.29	+51.08

Frame B

	M^- (1-k)	M^+ (1-k)
Total Moment	-136.5^{1-k}	$+73.5^{1-k}$
% to C.S.	75%	60%
Moment in C.S.	-102.38	+44.10
Moment in M.S.	-34.13	+29.4

Calculate Effective Depth

→ Moments in long direction are larger than in the short direction

↳ ∴ Need to put reinforcement lower in the long direction

$d_{long} = 9.00'' - 0.75'' - \frac{1}{2}(0.75'') = 7.875''$

$d_{short} = d_{long} - (\#6 \text{ bar diameter}) = 7.125''$

Appendix D: Two-Way Flat Plate Design

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Frame A → Interior Bays

Negative Moments

column strip = $(-177.86^{1\text{-}k}) / 8\text{ ft} = -22.23\ ^{k}/_{ft}$

middle strip = $(-59.29^{1\text{-}k}) / 18\text{ ft} = -3.29\ ^{k}/_{ft}$

Positive Moments

column strip = $(+76.61^{1\text{-}k}) / 8\text{ ft} = +9.58\ ^{k}/_{ft}$

middle strip = $(+51.08^{1k}) / 18\text{ ft} = +2.84\ ^{k}/_{ft}$

Frame B → Interior Bays

Negative Moments

column strip = $(-102.38^{1\text{-}k}) / 8\text{ ft} = -12.79\ ^{k}/_{ft}$

middle strip = $(-34.13^{1\text{-}k}) / 8\text{ ft} = -1.89\ ^{k}/_{ft}$

Positive Moments

column strip = $(+44.10^{1\text{-}k}) / 8\text{ ft} = +5.51\ ^{k}/_{ft}$

middle strip = $(+29.10^{1\text{-}k}) / 8\text{ ft} = +3.64\ ^{k}/_{ft}$

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 6

Design of Reinforcement → Column Strip → A

	M^- (1-K)	M^+ (1-K)
1.) M_u (1-K)	-177.86	+76.61
2.) C.S. width = b	96"	96"
3.) d_{long}	7.875"	7.875"
4.) $M_n = M_u/\phi = 0.9$	-197.62	+85.12
5.) $R = M_n / bd^2 \times 12000$	398.33	154.42
6.) ρ_{req} = Tables $R = \rho f_y (1 - 0.59\rho \frac{f_y}{f'_c})$	0.00708	0.00264
7.) $A_{s,required} = \rho bd$	5.35 in²	1.99 in²
8.) $A_{s,min} = (0.002)bt$	1.728 in²	1.728 in²
9.) $N = \frac{\text{Larger of 7 \& 8}}{\#6 \text{ Bar Area}}$	$\frac{5.35}{0.4481} = 11.9$	$\frac{1.99}{0.4481} = 4.44$
10.) $N_{min} = \frac{\text{Strip Width}}{2t}$	$\frac{96}{2(9)} = 5.33$	$\frac{96}{2(9)} = 5.33$
11.) Larger of 9 & 10	N = 12 #6 TOP BARS	N = 6 #6 BOT. BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 7

Design of Reinforcement → Middle Strip – A

	M^- (1-K)	M^+ (1-K)
1.) Mu (1-K)	−59.29	+51.08
2.) M.S. width = b	216"	216"
3.) d_{long}	7.875"	7.875"
4.) $M_n = M_u / \phi$ = 0.9	−65.88	+56.76
5.) $R = M_n / bd^2 \times 12000$	59.02	50.85
6.) ρ_{req} = Tables	0.000992	0.000854
7.) $A_{s,required} = \rho b d$	1.69 in²	1.45 in²
8.) $A_{s,min} = (0.002)bt$	3.89 in²	3.89 in²
9.) N = Larger of 7 & 8 / #6 Bar Area	3.89 / 0.4481 = 8.68	8.68
10.) N_{min} = Strip Width / 2t	216 / 2(9) = 12	12
11.) Larger of 9 & 10	N = 12 #6 TOP BARS	N = 12 #6 BOT BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 8

Design of Reinforcement → Column Strip → B

	M^- (1-K)	M^+ (1-K)
1.) M_u (1-K)	-102.38	+44.10
2.) C.S. width = b	96"	96"
3.) d_{short}	7.125"	7.125"
4.) $M_n = M_u / \phi\ 0.9$	-113.76	+49.0
5.) $R = M_n / bd^2 \times 12000$	280.11	120.65
6.) ρ_{req} = Tables	0.00488	0.00205
7.) $A_{s,required} = \rho bd$	3.34 in²	1.402 in²
8.) $A_{s,min} = (0.002)bt$	1.73 in²	1.73 in²
9.) $N = \frac{\text{Larger of 7 \& 8}}{\#6 \text{ Bar Area}}$	$\frac{3.34}{0.4481} = 7.45$	$\frac{1.73}{0.4481} = 3.86$
10.) $N_{min} = \frac{\text{Strip Width}}{2t}$	$\frac{96}{2(9)} = 5.33$	5.33
11.) Larger of 9 & 10	N = 8 #6 TOP BARS	N = 6 #6 BOT BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 9

Design of Reinforcement → Middle Strip - B

	$M^-(1-k)$	$M^+(1-k)$
1.) $M_u(1-k)$	-34.13	+29.4
2.) M.S width = b	96"	96"
3.) d_{short}	7.125"	7.125"
4.) $M_n = M_u/\phi$: 0.9	-37.92	+32.67
5.) $R = M_n/bd^2 \times 12000$	93.37	72.39
6.) ρ_{req} : Tables	0.00158	0.00122
7.) $A_{s,required} = \rho bd$	1.08 in^2	0.834 in^2
8.) $A_{s,min} = (0.002)bt$	1.73 in^2	1.73 in^2
9.) $N = \frac{\text{Larger of 7 \& 8}}{\#6 \text{ Bar Area}}$	$\frac{1.73}{0.4481} = 3.86$	3.86
10.) $N_{min} = \frac{\text{Strip Width}}{2t}$	5.33	5.33
11.) Larger of 9 & 10	N = 6 #6 TOP BARS	N = 6 #6 BOT. BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 10

Exterior Tranverse Distribution %'s

Item/Description	Frame A	Frame B
1.) Total Tranverse Width	164"	104"
2.) Column Strip Width	56"	56"
3.) Middle Strip Width	108"	48"
4.) Torsional Constant ↳ no beams → C = 0	0	0
5.) $I_s = \ell t^3/12$	6,318	6,318
6.) β_t	0	0
7.) α_1	0	0
8.) ℓ_2/ℓ_1	1.56	0.63
9.) $\alpha_1 \ell_2 \ell_1$	0	0
10.) M^+ % to C.S.	60%	60%
11.) M^- % to C.S.	75%	75%

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 11

Frame A → Exterior Bays

Negative Moments

column strip = (−177.86^1-k)/4.67' = −38.09 k/ft
middle strip = (−59.29^1-k)/9' = −6.59 k/ft

Positive Moments

column strip = (+76.61^1-k)/4.67' = +16.40 k/ft
middle strip = (+51.08^1k)/9' = +5.68 k/ft

Frame B → Exterior Bays

Negative Moments

column strip = (−102.38^1-k)/4.67' = −21.92 k/ft
middle strip = (−34.13^1-k)/4' = −8.53 k/ft

Positive Moments

column strip = (+44.10^1-k)/4.67' = +9.44 k/ft
middle strip = (+29.10^1-k)/4' = +7.28 k/ft

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 12

Design of Reinforcement → Column Strip → A

	$M^-(1-k)$	$M^+(1-k)$
1.) $M_u(1-k)$	-177.86	+76.61
2.) c.s. width = b	56"	56"
3.) d_{long}	7.875"	7.875"
4.) $M_n = M_u/\phi$	-197.62	+85.12
5.) $R = M_n/bd^2 \times 12000$	682.85	294.12
6.) ρ_{req}	0.0128	0.00514
7.) As, required	5.64 in^2	2.27 in^2
8.) $A_{s,min}$	1.008 in^2	1.008 in^2
9.) N = Larger of 7 & 8 / #6 Bar Area	$\frac{5.64}{0.4481} = 12.9$	$\frac{2.27}{0.4481} = 5.07$
10.) N_{min} = Strip width / 2t	3.11	3.11
11.) Larger of 9 & 10	N = 13 #6 TOP BARS	N = 6 #6 BOTTOM BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 13

Design of Reinforcement → Middle Strip → A

	$M^-(1-k)$	$M^+(1-k)$
1.) $M_u(1-k)$	-59.29	+51.08
2.) M.S. width = b	164"	164"
3.) d_{long}	7.875"	7.875"
4.) M_n	-65.88	+56.76
5.) R	77.73	66.97
6.) ρ_{req}	0.00131	0.00113
7.) $A_{s,req}$	1.69 in^2	1.46 in^2
8.) $A_{s\,min}$	2.95 in^2	2.95 in^2
9.) N	6.58	6.58
10.) N_{min}	9.11	9.11
11.) Larger of 9 & 10	N = 10 #6 TOP BARS	N = 10 #6 BOT. BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 14

Design of Reinforcement → column Strip → B

	$M^-(1-k)$	$M^+(1-k)$
1.) M_u (1-k)	-102.38	+44.10
2.) C.S. width = b	56"	56"
3.) d_{short}	7.125"	7.125"
4.) M_n	-113.76	+49.0
5.) R	480.19	206.83
6.) ρ_{req}	0.00867	0.00356
7.) $A_{s,req}$	3.46 in^2	1.42 in^2
8.) $A_{s,min}$	1.008 in^2	1.008 in^2
9.) N	7.72	3.17
10.) N_{min}	3.11	3.11
11.) Larger of 9 & 10	N = 8 #6 TOP BARS	N = 4 #6 BOT. BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab — 15

Design of Reinforcement → Middle Strip → B

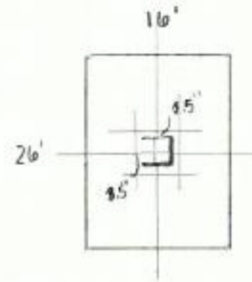
	$M^-(1-k)$	$M^+(1-k)$
1.) $M_u\ (1-k)$	-34.13	+29.4
2.) M.S width = b	104"	104"
3.) d_{short}	7.125"	7.125"
4.) M_n	-37.92	+32.67
5.) R	86.19	74.26
6.) ρ_{req}	0.00146	0.00125
7.) $A_{s,req.}$	1.08 in²	0.926 in²
8.) $A_{s,min}$	1.872 in²	1.872 in²
9.) N	4.18	4.18
10.) N_{min}	5.78	5.78
11.) Larger of 9 & 10	N = 6 #6 TOP BARS	N = 6 #6 BOT BARS

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab | 16

Design for Shear

$d = 10 - \underset{\text{cover}}{3/4} - 0.75 = 8.5''$



Frame A

$V_u = 0.299\,ksf\left(\frac{26}{2} - \frac{24''/2 + 8.5''}{12in/ft}\right)(16')$

$V_u = 54.02\,k$

$\phi V_n = \phi V_c = 0.75\left[2\lambda\sqrt{f'c}\,bd\right]$

$\phi V_c = 0.75(2)(1)\sqrt{5000}\,(16')(12in/ft)(8.5) = 173.1\,k$

$173.1\,k > 54.02\,k \quad \therefore$ ok ✓

Frame B

$V_u = 0.299\,ksf\left(\frac{16}{2} - \frac{24''/2 + 8.5''}{12in/ft}\right)(26')$

$V_u = 48.9\,k$

$\phi V_n = \phi V_c = 0.75\left[2\lambda\sqrt{f'c}\,bd\right]$

$\phi V_c = 0.75(2)(1)\sqrt{5000}\,(26')(12in/ft)(8.5) = 281.3\,k$

$281.3\,k > 48.9\,k \quad \therefore$ ok ✓

Appendix D: Two-Way Flat Plate Design

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Two-Way Punching Shear → Interior

$$V_n = 0.299\text{ ksf}\left[(26')(16') - \left[\frac{24+2(8.5/2)}{12\text{ in/ft}}\right]\left[\frac{24+2(8.5/2)}{12\text{ in/ft}}\right]\right] =$$

$$V_n = 122.2\text{ K}$$

$$b_o = 4[24+2(8.5/2)] = 130\text{ in.}$$

$$V_c = \min\begin{cases} 4\lambda\sqrt{f'c}\,b_o d = 4(1.0)(\sqrt{5000})(130)(8.5) = \boxed{312.54\text{ K}} \\ \left(2+\frac{4}{\beta}\right)\lambda\sqrt{f'c}\,b_o d = \left(2+\frac{4}{1}\right)(1.0)\sqrt{5000}(130)(8.5) = 468.8\text{ K} \\ \left(\frac{\alpha_s d}{b_o}+2\right)\lambda\sqrt{f'c}\,b_o d = \left[\frac{40(8.5)}{130}+2\right](1.0)\sqrt{5000}(130)(8.5) = 360.6^{K} \end{cases}$$

$\beta = \frac{24}{24} = 1$; $\alpha_s = 40$ for interior column

$$\phi V_c = 0.75(312.54\text{K}) = 234.41 > V_n = 122.2\text{K} \therefore \text{OK}$$

Two-Way Punching Shear → Edge Column

$$V_n = 0.299\text{ ksf}\left[(26')(9.25') - \left(\frac{24+2(8.5/2)}{12\text{ in/ft}}\right)\left(\frac{24+8.5/2}{12\text{ in/ft}}\right)\right] =$$

$$V_n = 70.0\text{ K}$$

$$b_o = 2[24+2(8.5/2)] + 2[24+8.5/2] = 121.5\text{ in}$$

$\alpha_s = 30$ for edge columns

$$V_c = \min\begin{cases} 4\lambda\sqrt{f'c}\,b_o d = 4(1)\sqrt{5000}(121.5)(8.5) = \boxed{292.1\text{ K}} \\ \left(2+\frac{4}{\beta}\right)\lambda\sqrt{f'c}\,b_o d = (2+4)(1)(\sqrt{5000})(121.5)(8.5) = 438.19\text{ K} \\ \left(\frac{\alpha_s d}{b_o}+2\right)\lambda\sqrt{f'c}\,b_o d = \left(\frac{30(8.5)}{121.5}+2\right)(1)\sqrt{5000}(121.5)(8.5) = 299.3^{k} \end{cases}$$

$$\phi V_c = 0.75(292.1\text{K}) = 219.1 > V_n = 70.0^{k} \therefore \text{OK}$$

Appendix D: Two-Way Flat Plate Design

Cody Scheller | Senior Thesis | Flat Slab 18

Two-Way Punching Shear → Corner Columns

$$V_n = 0.299\,ksf\left[(14.25')(9.25') - \left[\frac{24+\frac{8.5}{2}}{12}\right]\left[\frac{24+\frac{8.5}{2}}{12}\right]\right] =$$

$$V_n = 37.75\,k$$

$$b_o = 4\left[24 + \frac{8.5}{2}\right] = 113\,in$$

$$V_c = \min \begin{cases} 4\lambda\sqrt{f'_c}\,b_o d = 4(1.0)\sqrt{5000}(113)(8.5) = 271.7\,k \\ \left(2+\frac{4}{\beta}\right)\lambda\sqrt{f'_c}\,b_o d = (2+4)(1)(\sqrt{5000})(113)(8.5) = 407.5\,k \\ \left(\frac{\alpha_s d}{b_o}+2\right)\lambda\sqrt{f'_c}\,b_o d = \left(\frac{20(8.5)}{113}+2\right)(1)\sqrt{5000}(113)(8.5) = \boxed{238\,k} \end{cases}$$

$\alpha_s = 20$ for corner columns

$$\phi V_c = 0.75(238^k) = 178.5\,k > V_n = 37.75^k$$

∴ ok

→ No drop panels needed

Appendix D: Two-Way Flat Plate Design

Slab Weights				
Floor	Area (ft^2)	Perimeter (ft)	Weight of Concrete Slab (psf)	Total Slab Weight (kips)
1	19968	692	112.5	2246.4
2	19968	692	112.5	2246.4
3	19968	692	112.5	2246.4
4	19968	692	112.5	2246.4
5	19968	692	112.5	2246.4
6	19968	692	112.5	2246.4
7	19968	692	112.5	2246.4
Roof	19968	692	150	2995.2
		Total Slab Weight =		18720

Interior Bay Reinforcement - Long Direction		
Bar Position	Bar Size	Number of Bars
Column Strip		
Top Bars	#6	12
Bottom Bars	#6	6
Middle Strip		
Top Bars	#6	12
Bottom Bars	#6	12

Interior Bay Reinforcement - Short Direction		
Bar Position	Bar Size	Number of Bars
Column Strip		
Top Bars	#6	8
Bottom Bars	#6	6
Middle Strip		
Top Bars	#6	6
Bottom Bars	#6	6

Exterior Bay Reinforcement - Long Direction		
Bar Position	Bar Size	Number of Bars
Column Strip		
Top Bars	#6	13
Bottom Bars	#6	6
Middle Strip		
Top Bars	#6	10
Bottom Bars	#6	10

Exterior Bay Reinforcement - Short Direction		
Bar Position	Bar Size	Number of Bars
Column Strip		
Top Bars	#6	8
Bottom Bars	#6	4
Middle Strip		
Top Bars	#6	6
Bottom Bars	#6	6

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design | 1

Check Column on Bottom Floor → Corner Column

→ (16"x16") Column

$13' = 156" = \ell_c$

use load case 1.2D + 1.0L + 1.6W

$\Sigma P_u = 866.24$ kips

$V_{us} = 969.54$

$\Delta_o = 0.13$

→ Is it a sway frame? (ACI 10.10.5.2)

$$Q = \frac{\Sigma P_u \Delta_o}{V_{us} \ell_c} \leq 0.05$$

$$Q = \frac{866.24(0.13)}{969.54(156)} = 0.00074 < 0.05 \checkmark$$

∴ Nonsway Frame

→ Check Slenderness

$$\frac{k \ell_u}{r} \leq 22$$

$k = 1.0$ (for nonsway)

$\ell_n = 168"$

$r = 0.3h = 0.3(16) = 4.8$

$$\frac{1.0(156)}{4.8} = 32.5 > 22$$ → Column is slender

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design | 2

→ Moment Magnification Factor

$M_c = \delta_{ns} M_2$

$P_u = 502\text{k}$

$M_2 = 135 \text{ in-k}$

$M_1 = 0$

$C_m = 0.6 + 0.4(M_1/M_2) = 0.6$

$P_c = \frac{\pi^2 EI}{(k l_u)^2} = 40406.59\text{k}$

$EI_{eff} = \frac{0.4 E_c I_g}{1 + \beta_{dns}} = \frac{0.4(3600)(16^4/12)}{1+1.0} = 3.93 \times 10^6 \text{ k-in}^2$

$\delta_{ns} = \frac{C_m}{1 - \frac{P_u}{0.75 P_c}} = 0.6 < 1.0$ → Moment magnification does not influence column behavior.

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design 3

Interior Column → First Floor

→ column size: 20" x 20" → First Four Floors column size

→ P_u = 780.83 kips

→ assume $\rho_g = 0.03$

Required Area of the column

$$A_g = \frac{P_u}{0.8\phi\left[0.85 f'_c (1-\rho_g) + f_y \rho_g\right]}$$

$$A_g = \frac{780.83\text{ k}}{0.8(0.65)\left[0.85(4)(1-0.03)+60(0.03)\right]}$$

$$A_g = 294.55\text{ in}^2$$

$294.55\text{ in}^2 < (20\text{ in} \times 20\text{ in}) = 400\text{ in}^2$ ∴ ok

→ still use 20" x 20" column on first floor to be conservative.

Required Amount of Steel

$$A_{st} = \left|\frac{P_u - 0.8\phi(0.85 f'_c A_g)}{0.8\phi(f_y - 0.85 f'_c)}\right| \text{ or } A_{st} = \rho bd = (0.03)(20)(20) = 12\text{ in}^2 \text{ (controls)}$$

$$= \frac{780.83 - (0.8)(0.65)(0.85 \times 4 \times 400)}{(0.8)(0.65)(60 - (0.85)(4))} = 2.5\text{ in}^2$$

∴ use 12 #9 bars → $12(1.00) = 12\text{ in}^2$

→ $12\text{ in}^2 = 12\text{ in}^2$ ∴ ok

Ties → #3 ties

$S_{max} = \min[16d_b, 48d_t, b_{min}] = \min[18, 18, 20] = 18$ in

use #3 ties @ 18 in

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design | 4

Corner Column → First Floor

→ column size: 16" x 16" → All Floors

→ $P_u = 221.49$ kips

→ assume $\rho_g = 0.03$

Required Area of the column

$$A_g = \frac{P_u}{0.8\phi[0.85f'_c(1-\rho_g)+f_y\rho_g]}$$

$$A_g = \frac{221.49}{0.8(0.65)[(0.85)(4)(1-0.03)+60(0.03)]}$$

$A_g = 84.6\ in^2 < 256\ in^2$ → 16" x 16" columns ok

Required Amount of Steel

$$A_{st} = \left|\frac{P_u - 0.8\phi[0.85f'_cA_g]}{0.8\phi(f_y - 0.85f'_c)}\right| \text{ or } A_{st} = \rho bd = (0.03)(16)(16) = 7.68\ in^2$$

↑ controls.

$$= \left|\frac{221.49 - 0.8(0.65)[0.85 \times 4 \times 256]}{0.8(0.65)[60 - 0.85(4)]}\right| = \boxed{7.85\ in^2}$$

∴ use 8 #9 bars → $8(1.00) = 8\ in^2$

→ $8\ in^2 > 7.85\ in^2$ ∴ ok

Ties → #3 ties

$S_{max} = \min[16d_B, 48d_t, b_{min}] = \min[18, 18, 16] = 16\ in$

use #3 ties @ 16 in

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design 5

Exterior Column Design → First Floor

→ column size: 16" x 16" → All Floors

→ $P_u = 677.74$ kips

→ assume $\rho_g = 0.03$

Required Area of the Column

$$A_g = \frac{P_u}{0.8\,\Phi\left[0.85 f'_c (1-\rho_g) + f_y \rho_g\right]}$$

$$A_g = \frac{677.74\ k}{0.8(0.65)\left[0.85(4)(1-0.03)+60(0.03)\right]}$$

$A_g = 255.66\ in^2 < 256\ in^2$ → 16" x 16" columns ok ✓

Required Amount of Steel

$$A_{st} = \left| \frac{P_u - 0.8\phi(0.85 f'_c A_g)}{0.8\phi(f_y - 0.85 f'_c)} \right| \quad \text{or} \quad A_{st} = \rho b d = (0.03)(16)(16) = 7.68\ in^2$$

↕ same

$$= \frac{677.74 - (0.8)(0.65)(0.85 \times 4 \times 256)}{(0.8)(0.65)\left[60 - 0.85(4)\right]} = 7.65\ in^2$$

∴ use 8 #9 bars → $8(1.00) = 8\ in^2$

→ $8\ in^2 > 7.65\ in^2$ ∴ ok

Ties → #3 ties

$S_{max} = \min[16 d_b, 48 d_t, b_{min}] = \min[18, 18, 16] = 16\ in$

use #3 ties @ 16in.

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design | 6

Interior Column → Fifth Floor

→ column size: 16" x 16"

→ P_u = 435.76 kips

→ assume ρ_g = 0.03

Required Area of the Column

$$A_g = \frac{P_u}{0.8\phi[0.85f'_c(1-\rho_g) + f_y\rho_g]}$$

$$A_g = \frac{435.76 \text{ kips}}{0.8(0.65)[0.85(4)(1-0.03) + 60(0.03)]}$$

A_g = 164.38 in² < 256 in² → ∴ use 16" x 16" columns

Required Amount of Steel

$$A_{st} = \frac{P_u - 0.8\phi(0.85f'_cA_g)}{0.8\phi(f_y - 0.85f'_c)}$$ or $A_{st} = \rho bd = (0.03)(16)(16) = 7.68 \text{ in}^2$ ← controls.

$$= \frac{435.76 - (0.8)(0.65)[0.85 \times 4 \times 256]}{(0.8)(0.65)[60 - 0.85(4)]} = 0.57 \text{ in}^2$$

∴ use 8 #9 bars → 8(1.00) = 8 in²

8 in² > 7.68 in² → ∴ OK

Ties → #3 ties

$S_{max} = \min[16d_b, 48d_t, b_{min}] = \min[18, 18, 16] = 16$ in.

use #3 ties @ 16 in.

Appendix E: Column Design

Cody Scheller | Senior Thesis | Column Design | 7

→ Check P_o for each

$P_o = 0.85 f_c (A_g - A_{st}) + f_y A_{st}$

$\phi P_n = \phi r P_o > P_u$

→ Interior Column → First Floor

$P_o = (0.85)(4)(400-12) + (60)(12) = 2039.2$

$\phi P_n = \phi r P_o = (0.65)(0.8)(2039.2) = 1060.38\ k$

$1060.38 > 783.83$ ✓ ok

→ Corner Column → First Floor

$P_o = (0.85)(4)(256-7.85) + (60)(7.85) = 1314.71\ k$

$1314.71\ k > 221.49\ k$ ✓ ok

→ Exterior Column → First Floor

$P_o = (0.85)(4)(256-7.68) + (60)(7.68) = 1305.09\ k$

$1305.09\ k > 677.74$ kips

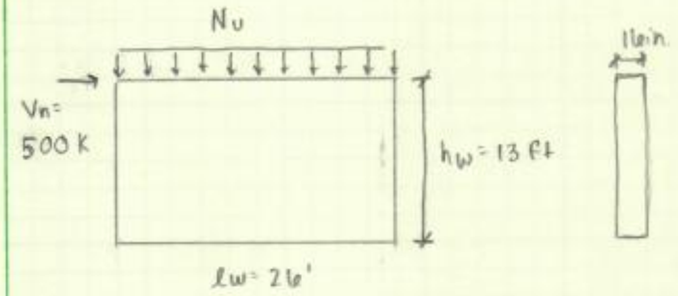
→ Exterior Column → Fifth Floor

$P_o = (0.85)(4)(256-7.68) + 60(7.68) = 1305.09\ k$

$1305.09\ k > 435.76\ k$

Appendix F: Shear Wall Design

Cody Scheller | Senior Thesis | Shear Walls | 1



N_u = self weight of shear walls above (84')

$N_u = (84')(16in/12in/ft)(26')(150pcf) = 436.8\,k$

$\phi V_n \geq V_n = V_c + V_s$

V_c

Simplified Method:

$V_c \leq 2\sqrt{f'_c}\,hd$ $\qquad d = 0.8\,l_n$

$\leq 2\sqrt{4000}(13)(249.6)/1000$ $\qquad = 0.8(26\times12) = 249.6\,in$

$= 410.44\,k$ ← USE THIS

Other: (min of 1 or 2)

① $V_c \leq 3.3\sqrt{f'_c}\,hd + \dfrac{N_u d}{4 l_w}$

$\leq (3.3)\sqrt{4000}(16)(249.6)/1000 + \dfrac{436.8(249.6)}{4(26\times12)}$

$V_c \leq 920.9\,k$

② $V_c \leq \left[0.6\sqrt{f'_c} + \dfrac{l_w(1.25\sqrt{f'_c} + 0.2N_u/l_w h)}{M_u/V_u - l_w/2}\right]hd$

$M_u = 500(13) = 6500'^k = 78000\,in\text{-}k$

$V_c \leq \left[0.6\sqrt{4000} + \dfrac{(26\times12)(1.25\sqrt{4000} + 0.2(249.6)/(26\times12\times13))}{\frac{78000}{500}}\right](13)(249.6)$

$V_c \leq 636.2\,k$

Appendix F: Shear Wall Design

Cody Scheller | Senior Thesis | Shear Walls | 2

→ Horizontal Reinforcement

$\frac{1}{2}\phi V_c = \frac{1}{2}(0.75)(410.44) = 153.9k < 500k$

∴ Needs Reinforce.

$V_u \le \phi V_n = \phi(V_c + V_s)$

$500 = 0.75(410.44 + V_s)$ → $V_s = 256.23$

→ Try 2-#4 @ 10"

$V_s = \frac{A_v f_y d}{s} = \frac{2(0.2)(60)(249.6)}{10} = 599.04 > 256.23$ ∴ ok ✓

$\rho_t = \frac{A_v}{sh} = \frac{2(0.2)}{10(13)} = 0.003 \ge 0.0025$ ✓ ok.

$s \le \begin{cases} \ell_w/5 = 26(12)/5 = 62.4\text{in} \\ 3h = 3(13) = 39\text{in} \\ 18\text{in.} \leftarrow \text{controls} \end{cases}$

18in > 10in ✓ ∴ ok

∴ use 2-#4 @ 10" o.c. for horizontal reinforcement

→ Vertical Reinforcement

$\rho_\ell = \frac{A_v}{sh} \ge 0.0025 + 0.5\left(2.5 - \frac{h_w}{\ell_w}\right)(\rho_t - 0.0025)$

$\rho_\ell = 0.003 \ge 0.0022$

∴ use 2-#4 @ 10" o.c. for vertical reinforcement

Appendix F: Shear Wall Design

Cody Scheller | Senior Thesis | Shear Walls | 3

Flexural Design

$C = T$

$0.85 f'c\, b a = A_s f_y$

$M_u = A_s f_y \left(d - \frac{a}{2}\right)$ or $M_u = A_s f_y (jd)$ → $jd = 0.9d$

→ $d = 249.6 \text{ in}$

→ $jd = 0.9 (249.6 \text{ in}) = 224.64$

→ $M_u = 500 (13) = 6500'^{k}$

→ $M_u = \phi M_n = \phi A_s f_y j d$

$= 6500 (12 \text{in/ft}) = 0.9 A_s (60)(224.64)$

$A_s = 6.4 \text{ in}^2$

$C = T$

$a = \frac{A_s f_y}{0.85 f'c\, b} = \frac{6.4 \text{in}^2 (60000)}{0.85 (4000)(16)} = 7.06 \text{in}$

$jd = d - \frac{a}{2} = 249.6 - \frac{7.06}{2} = 246.07$

$A_s = \frac{6500 (12)}{0.9 (60)(246.07)} = 5.87 \text{in}^2$

Try 6 - #9s, $A_s = 6.0 \text{in}^2$

Appendix F: Shear Wall Design

Cody Scheller | Senior Thesis | Shear Walls | 4

→ Tension Controlled Section

$d_t = 26.0'(12in/ft) - 3'' = 309in$

$C = T$

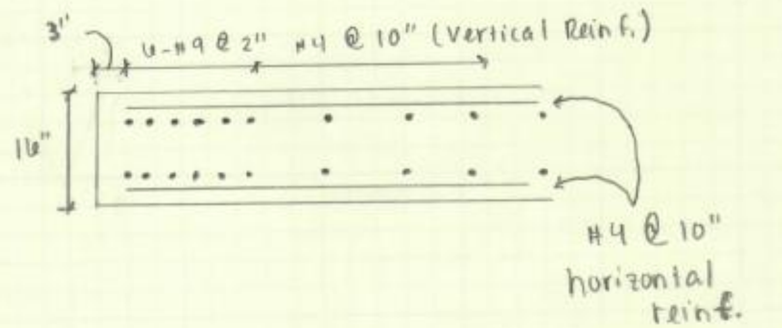
$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{6(60000)}{0.85(4000)(16)} = 6.62in$$

$$c = \frac{a}{B_1} = \frac{6.62in}{0.85} = 7.79in$$

$$\varepsilon_t = \varepsilon_u \left(\frac{d_t - c}{c}\right) = 0.003\left(\frac{309 - 7.79}{7.79}\right) =$$

$\rightarrow = 0.116 > 0.005$ ∴ ok ✓

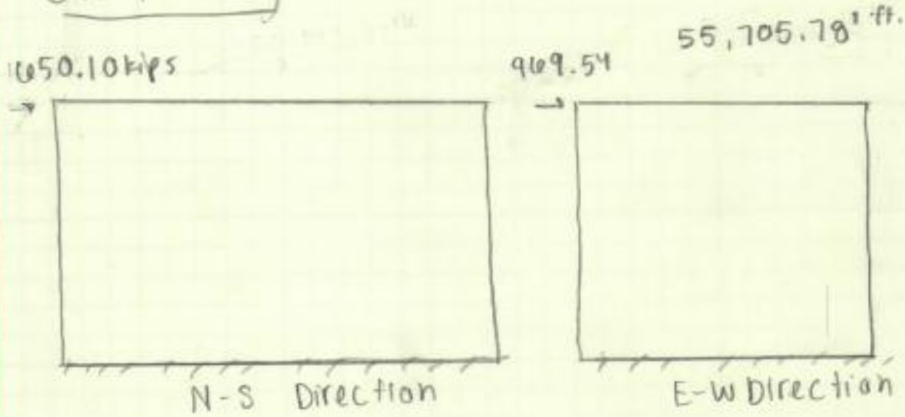
∴ Tension controls.



Appendix G: Overturning Calculation

Cody Scheller | Senior Thesis 1

Overturning



→ Seismic Loads control in N-S Direction

→ Wind Loads control in E-W Direction.

→ Overturning moments caused from lateral forces will be conteracted by the Dead Loads. → for Seismic

foundation Area = 21216

Building weight = 26000 k

Stress due to dead load

$= \frac{\text{Building Weight}}{\text{foundation Area}} = \frac{26000}{21216} = 1.23 \times 1000\text{ lb} =$ 1225.5 psf

Stress due to Seismic

$= \frac{1650.1(1000)}{21216} = 30.64$ $\quad \frac{30.64}{1225.5} = 2.5\%$ of dead load.

∴ ok

Appendix G: Overturning Calculation

Cody Scheller | Senior Thesis | 2

Overturning

→ For the wind load, the resisting moment needs to be greater than the moment the wind puts on the building.

$$M_r = \text{weight of building} \times \frac{\text{width}}{2}$$

$$= 26000^{k} \times \frac{96'}{2} = 1248000^{'k}$$

$$1{,}248{,}000^{'k} > 55{,}705.78^{'k}$$

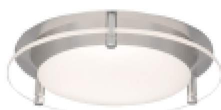
∴ ok

Appendix H: Lighting Breadth Material

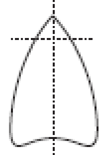
gotham®

Luminaire Type:
Catalog Number (autopopulated):

Ring



Disk



Gotham Architectural Downlighting
Decorative LED Downlights

6" Evo®
A-Series LED, Drop Luminous Ring/Disk

Solid-State Lighting

FEATURES

OPTICAL SYSTEM
- Self-flanged semi-specular, matte-diffuse or specular lower reflector
- Patented Bounding Ray™ optical design (U.S. Patent No. 5,800,050)
- 45° cutoff to source and source image
- Decorative element: 3/16"-thick low-iron glass with polished edges and sandblasted finish
- Precision-machined aluminum hardware with threaded spacers

MECHANICAL SYSTEM
- 16-gauge galvanized steel construction; maximum 1-1/4" ceiling thickness
- Telescopic mounting bars maximum of 32" and minimum of 15", preinstalled, 4" vertical adjustment
- Toolless adjustments post installation
- Junction box capacity: 8 (4 in, 4 out) 12AWG rated for 90°C
- Light engine and driver accessible through aperture

ELECTRICAL SYSTEM
- Fully serviceable and upgradeable LED light engine
- 70% lumen maintenance at 50,000 hours based on IESNA LM-79-2008
- 120-277VAC, 50/60hz power supply with 0-10V dimming (10-100%); rated for 50,000-hour life
- Overload and short circuit protected

LISTINGS
- Fixtures are CSA certified to meet US and Canadian standards; wet location, covered ceiling

WARRANTY
- 5-year limited warranty. Complete warranty terms located at: www.acuitybrands.com/CustomerResources/Terms_and_conditions.aspx

ORDERING INFORMATION

EXAMPLE: ALED 35/10 6AR DLR 120

Series	Color temperature	Nominal lumen values	Aperture/Trim color	Decorative element	Finish	Voltage
ALED	**27/** 2700 K	**10** 1000 lumens	**6AR** Clear	**DLR** Drop luminous ring	(blank) Semi-specular	**MVOLT**
	30/ 3000 K	**14** 1400 lumens	**6PR** Pewter	**DLD** Drop luminous disk	**LD** Matte diffuse	**120**
	35/ 3500 K	**18** 1800 lumens	**6WTR** Wheat		**LS** Specular	**277**
	41/ 4100 K		**6GR** Gold			**347**
			6WR[1] White			

Driver	Options	
(blank)[2] 0-10V dimming driver. Minimum dimming level 10%	**SF** Single fuse	**TRBL** Black painted flange
ECOS3[2,3] Lutron Hi-Lume® dimming driver. Minimum dimming level 1%	**LRC** Lithonia Reloc® system	**ELR**[5] Emergency battery pack with remote test switch
	NSD[4] Sensor Switch nLight™ dimming relay	**CP** Chicago plenum
	TRW[1] White painted flange	

ACCESSORIES order as separate catalog numbers (shipped separately)
ISD BC 0-10V wallbox dimmer. Refer to ISD-BC.

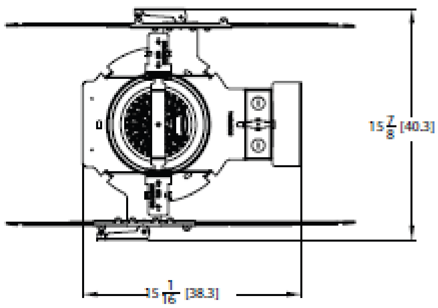
Appendix H: Lighting Breadth Material

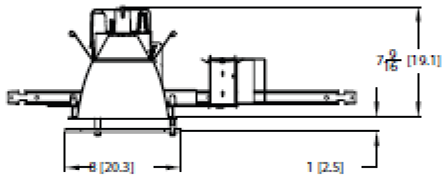
6" EVO
A-Series LED, Drop Luminous Ring/Disk
Solid-State Lighting

gotham

DIMENSIONAL DATA

All dimensions are inches (centimeters) unless otherwise noted.





Aperture: 6-1/4 (15.9)
Ceiling Opening: 7-1/8 (18.1)
Overlap Trim: 7-3/4 (19.6)

Appendix H: Lighting Breadth Material

gotham

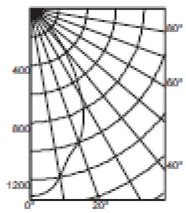
6" EVO
A-Series LED, Drop Luminous Ring/Disk
Solid-State Lighting

PHOTOMETRY

Distribution Curve | Distribution Data | Output Data | Coefficient of Utilization | Illuminance: Single Luminaire 30" Above Floor

ALED 35/18 6AR DLD

INPUT WATTS: 37, DELIVERED LUMENS: 1505, LM/W=40.7, 0.9 S/MH, TEST NO. LTL19773



	Ave	Lumens
0	1318	
5	1283	120
15	1069	304
25	888	402
35	534	334
45	220	175
55	84	77
65	52	52
75	30	31
85	9	11
90	0	

Zone	Lumens	% Lamp
0° - 30°	826.0	54.9
0° - 40°	1159.8	77.0
0° - 60°	1411.7	93.8
0° - 90°	1505.3	100.0
90° - 180°	0.0	0.0
0° - 180°	1505.3	*100.0

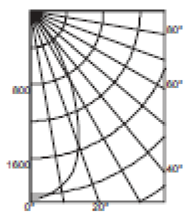
*Efficiency

pf	20%								
pc	80%			70%			50%		
pw	50%	30%	10%	50%	30%	10%	50%	30%	10%
0	119	119	119	116	116	116	111	111	111
1	109	106	103	106	104	101	102	100	98
2	99	94	90	97	93	89	94	90	87
3	91	85	80	89	84	79	87	82	78
4	83	77	72	82	76	71	80	75	70
5	77	70	65	76	70	65	74	69	64
6	71	64	59	71	64	59	69	63	59
7	66	59	55	66	59	54	64	58	54
8	62	55	50	61	55	50	60	54	50
9	58	51	47	57	51	47	56	51	46
10	54	48	43	54	48	43	53	47	43

	Initial FC	50% beam - 50.1°		10% beam - 83.5°	
Mounting Height	Center Beam	Diameter	FC	Diameter	FC
8.0	43.6	5.1	21.8	9.8	4.4
10.0	23.4	7.0	11.7	13.4	2.3
12.0	14.6	8.9	7.3	17.0	1.5
14.0	10.0	10.7	5.0	20.5	1.0
16.0	7.2	12.6	3.6	24.1	0.7

ALED 35/18 6AR DLR

INPUT WATTS: 37, DELIVERED LUMENS: 1696, LM/W=45.8, 0.9 S/MH, TEST NO. LTL19774



	Ave	Lumens
0	2062	
5	2015	190
15	1803	498
25	1215	552
35	528	320
45	81	72
55	32	30
65	19	19
75	11	11
85	4	5
90	0	

Zone	Lumens	% Lamp
0° - 30°	1239.4	73.1
0° - 40°	1559.8	91.9
0° - 60°	1662.2	98.0
0° - 90°	1696.6	100.0
90° - 180°	0.0	0.0
0° - 180°	1696.6	*100.0

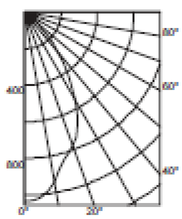
*Efficiency

pf	20%								
pc	80%			70%			50%		
pw	50%	30%	10%	50%	30%	10%	50%	30%	10%
0	119	119	119	116	116	116	111	111	111
1	110	108	106	108	106	104	104	102	101
2	103	99	95	101	97	94	98	95	92
3	96	91	87	94	90	86	92	88	85
4	90	86	80	88	83	79	86	82	78
5	84	78	74	83	78	74	81	76	73
6	79	73	69	78	73	68	77	72	68
7	74	68	64	74	68	64	72	67	64
8	70	66	60	70	64	60	69	63	60
9	66	61	57	66	60	56	65	60	56
10	63	57	53	62	57	53	62	57	53

	Initial FC	50% beam - 46.9°		10% beam - 73.3°	
Mounting Height	Center Beam	Diameter	FC	Diameter	FC
8.0	67.5	4.8	33.7	8.2	6.7
10.0	36.3	6.5	18.1	11.2	3.6
12.0	22.6	8.2	11.3	14.1	2.3
14.0	15.4	10.0	7.7	17.1	1.5
16.0	11.2	11.7	5.6	20.1	1.1

ALED 35/14 6AR DLD

INPUT WATTS: 30, DELIVERED LUMENS: 1167, LM/W=38.9, 0.9 S/MH, TEST NO. LTL19772



	Ave	Lumens
0	1096	
5	1085	94
15	835	237
25	691	313
35	412	258
45	168	134
55	65	60
65	40	40
75	23	24
85	7	8
90	0	

Zone	Lumens	% Lamp
0° - 30°	644.3	55.2
0° - 40°	901.9	77.3
0° - 60°	1095.0	93.8
0° - 90°	1167.4	100.0
90° - 180°	0.0	0.0
0° - 180°	1167.4	*100.0

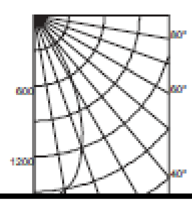
*Efficiency

pf	20%								
pc	80%			70%			50%		
pw	50%	30%	10%	50%	30%	10%	50%	30%	10%
0	119	119	119	116	116	116	111	111	111
1	109	106	103	106	104	101	102	100	98
2	99	94	90	97	93	89	94	90	87
3	91	85	80	89	84	79	87	82	78
4	86	77	72	82	76	71	80	75	71
5	77	70	65	76	70	65	74	69	64
6	72	65	60	71	64	59	69	63	59
7	67	60	55	66	59	55	64	59	54
8	62	55	51	61	55	50	60	54	50
9	58	51	47	58	51	47	57	51	47
10	55	48	44	54	48	44	53	47	43

	Initial FC	50% beam - 49.7°		10% beam - 83.2°	
Mounting Height	Center Beam	Diameter	FC	Diameter	FC
8.0	34.2	5.1	17.1	9.8	3.4
10.0	18.4	6.9	9.2	13.3	1.8
12.0	11.5	8.8	5.7	16.9	1.1
14.0	7.8	10.7	3.9	20.4	0.8
16.0	5.7	12.5	2.8	24.0	0.6

ALED 35/14 6AR DLR

INPUT WATTS: 31, DELIVERED LUMENS: 1315, LM/W=42.4, 0.9 S/MH, TEST NO. LTL19771



	Ave	Lumens
0	1601	
5	1578	148
15	1404	388
25	945	429
35	405	247
45	62	55
55	24	23
65	14	14
75	8	8
85	3	3
90	0	

Zone	Lumens	% Lamp
0° - 30°	986.8	75.3
0° - 40°	1211.4	92.1
0° - 60°	1289.6	98.0
0° - 90°	1315.9	100.0
90° - 180°	0.0	0.0
0° - 180°	1315.9	*100.0

*Efficiency

pf	20%								
pc	80%			70%			50%		
pw	50%	30%	10%	50%	30%	10%	50%	30%	10%
0	119	119	119	116	116	116	111	111	111
1	111	108	106	108	106	108	104	102	101
2	103	99	95	101	97	94	98	95	92
3	96	91	87	94	90	86	92	88	85
4	90	84	80	89	83	79	86	82	78
5	84	78	74	83	78	74	81	77	73
6	79	73	69	78	73	69	77	72	68
7	74	69	64	74	68	64	73	67	64
8	70	64	60	70	64	60	69	64	60
9	67	61	57	66	60	57	65	60	56
10	63	57	54	63	57	53	62	57	53

	Initial FC	50% beam - 46.6°		10% beam - 73.1°	
Mounting Height	Center Beam	Diameter	FC	Diameter	FC
8.0	52.9	4.7	26.5	8.2	5.3
10.0	28.5	6.5	14.2	11.1	2.8
12.0	17.7	8.2	8.9	14.1	1.8
14.0	12.1	9.9	6.1	17.1	1.2
16.0	8.8	11.6	4.4	20.0	0.9

Appendix H: Lighting Breadth Material

Lumen Method Calculations

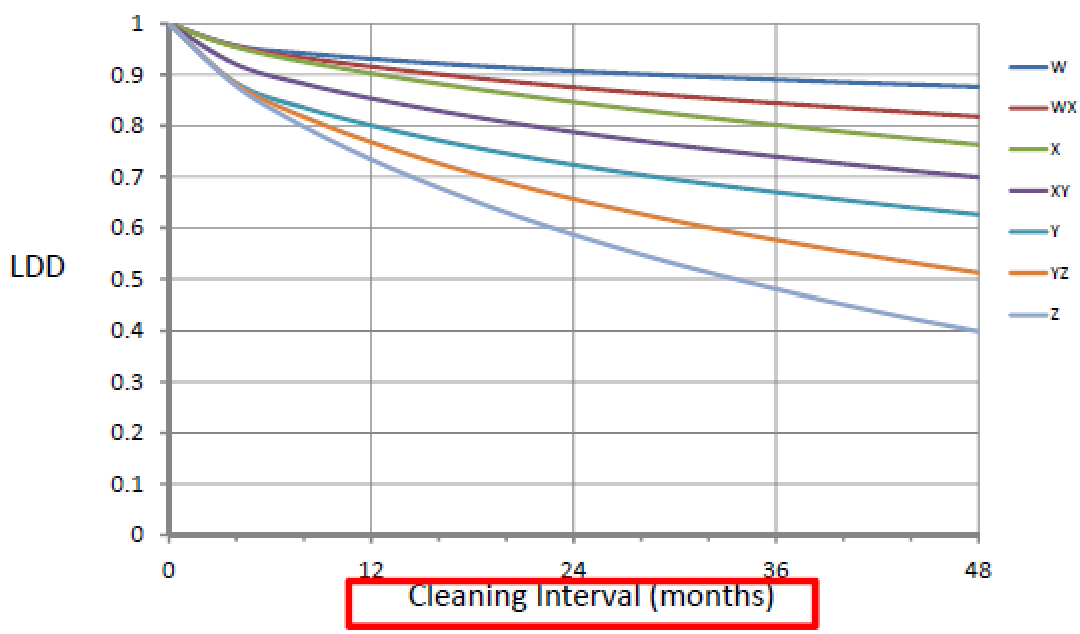
Lobby Luminaire:

Light Loss Factors(LLF)

- Lamp Lumen Depreciation(LLD) = LED Life = 0.7
- Luminaire Dirt Depreciation(LDD) = Clean, Direct, Open/Unvented

  = W + 24 Month Cleaning Interval = 0.91 = From Tables

Environment	Luminaire	DIRECT	SEMI-DIRECT	DIRECT-INDIRECT	SEMI-INDIRECT	INDIRECT
CLEAN	Open/Unvented	W	W	W	X	X
	Other	W	W	W	X	X
MODERATE	Open/Unvented	XY	XY	XY	Y	Y
	Other	X	X	X	Y	Y
DIRTY	Open/Unvented	Z	Z	Z	Z	Z
	Other	Y	Y	Y	Z	Z



Appendix H: Lighting Breadth Material

- Ballast Factor(BF) = 1.00
- Room Surface Dirt Depreciation = Direct, 10%, RCR of 5 = 0.96 = From Tables
- LLF = 0.7 x 0.91 x 1.00 x 0.96 = 0.61152

Room Cavity Ratio(RCR)

- $RCR = \dfrac{5 \times \text{Cavity Height} \times (\text{Cavity Length} + \text{Cavity Width})}{(\text{Cavity Length} \times \text{Cavity Width})}$

- $RCR = \dfrac{5 \times (12ft) \times (20ft + 30ft)}{(20ft \times 30ft)} = 5$

Coefficient of Utilization(CU)

- CU = 0.88 = Interpolated = From Tables in Photometric Viewer
- Reflectance's = 80/60/20

COEFFICIENTS OF UTILIZATION - ZONAL CAVITY METHOD

EFFECTIVE FLOOR CAVITY REFLECTANCE: 20%

RCC %:	80				70				50			30			10			0
RW %:	70	50	30	0	70	50	30	0	50	30	20	50	30	20	50	30	20	0
RCR: 0	1.19	1.19	1.19	1.19	1.16	1.16	1.16	1.00	1.11	1.11	1.11	1.06	1.06	1.06	1.02	1.02	1.02	1.00
1	1.13	1.11	1.08	1.06	1.11	1.08	1.06	.94	1.04	1.02	1.01	1.01	.99	.98	.97	.96	.95	.93
2	1.08	1.03	.99	.95	1.05	1.01	.97	.87	.98	.95	.92	.95	.92	.90	.92	.90	.88	.87
3	1.02	.96	.91	.87	1.00	.94	.90	.82	.92	.88	.85	.89	.86	.83	.87	.84	.82	.81
4	.97	.90	.84	.80	.95	.89	.83	.76	.86	.82	.78	.84	.81	.78	.82	.79	.77	.75
5	.92	.84	.78	.74	.91	.83	.78	.71	.81	.77	.73	.80	.76	.72	.78	.75	.72	.70
6	.88	.79	.73	.69	.86	.78	.73	.67	.77	.72	.68	.75	.71	.68	.74	.70	.67	.66
7	.84	.74	.69	.64	.82	.74	.68	.63	.73	.67	.64	.71	.67	.63	.70	.66	.63	.62
8	.80	.70	.64	.60	.79	.70	.64	.59	.69	.64	.60	.68	.63	.60	.67	.63	.59	.58
9	.76	.67	.61	.57	.75	.66	.60	.56	.65	.60	.56	.64	.60	.56	.63	.59	.56	.55
10	.73	.63	.57	.54	.72	.63	.57	.53	.62	.57	.53	.61	.56	.53	.60	.56	.53	.52

Lumen Method

- $E_{avg} = \dfrac{(\text{luminaires}) \times (\text{lamps/luminaire}) \times (\text{lumens/lamp}) \times (CU) \times (LLF)}{\text{Room Area}}$
- $E_{avg} = \dfrac{(12) \times (1) \times (1315 \text{ lumens}) \times (0.88) \times (0.612)}{(600ft^2)} = 14.2$ footcandles
- Use 12 Gotham 6" LED Downlights

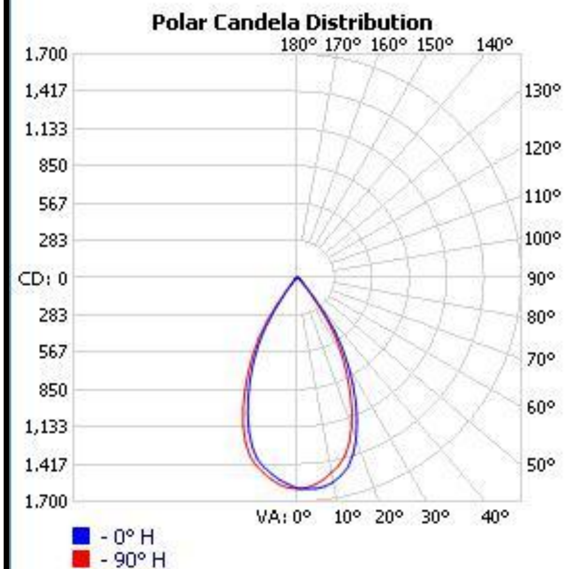
Appendix H: Lighting Breadth Material

INDOOR PHOTOMETRIC REPORT
CATALOG: ALED 35/14 6AR DLR

AcuityBrands gotham

TEST #:	LTL19771
CATALOG #:	ALED 35/14 6AR DLR
LUMINAIRE:	6" LED DOWNLIGHT 3500K/1400 LUMENS WITH DECORATIVE GLASS RING
LAMP:	ONE 31-WATT LED, DOWNLIGHT POS.
LAMP OUTPUT:	1 LAMP, TOTAL LUMINAIRE LUMENS: 1315.8 TEST BASED ON ABSOLUTE PHOTOMETRY *
BALLAST:	XITANIUM LEDINTA1000C60DB
INPUT WATTAGE:	31.1
LUMINOUS OPENING:	CIRCULAR (DIA: 6")
CIE CLASS:	DIRECT
MAX CD:	1,609.0 AT HORIZONTAL: 0°, VERTICAL: 5°
SPACING CRITERION:	@ 0 = 0.92 @ 90 = 0.86

PRODUCT LINKS
IES LDT PDF



Appendix H: Lighting Breadth Material

INDOOR PHOTOMETRIC REPORT
CATALOG: ALED 35/14 6AR DLR

AcuityBrands.

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LUMINAIRE
0-30	964.7	73.3%
0-40	1,211.4	92.1%
0-60	1,289.6	98%
60-90	26.2	2%
70-100	11.9	0.9%
90-120	0	0%
0-90	1,315.8	100%
90-180	0	0%
0-180	1,315.8	100%

LUMENS PER ZONE

ZONE	LUMENS	% TOTAL	ZONE	LUMENS	% TOTAL
0-10	148.3	11.3%	90-100	0	0%
10-20	387.7	29.5%	100-110	0	0%
20-30	428.7	32.6%	110-120	0	0%
30-40	246.7	18.7%	120-130	0	0%
40-50	55.4	4.2%	130-140	0	0%
50-60	22.8	1.7%	140-150	0	0%
60-70	14.3	1.1%	150-160	0	0%
70-80	8.5	0.6%	160-170	0	0%
80-90	3.4	0.3%	170-180	0	0%

AVERAGE LUMINANCE (CD/M2)

	0	22.5	45	67.5	90	112.5	135	157.5	180
0	87767	87767	87767	87767	87767	87767	87767	87767	87767
45	5815	5272	4962	4729	4652	4652	4652	4497	4186
55	2676	2485	2389	2294	2294	2294	2294	2198	2103
65	2075	1946	1946	1816	1816	1816	1816	1816	1686
75	1906	1694	1906	1694	1694	1694	1694	1694	1483
85	2516	1887	2516	1887	2516	1887	1887	1887	1887

COEFFICIENTS OF UTILIZATION - ZONAL CAVITY METHOD

EFFECTIVE FLOOR CAVITY REFLECTANCE: 20%

RCC %:	80				70				50			30			10			0
RW %:	70	50	30	0	70	50	30	0	50	30	20	50	30	20	50	30	20	0
RCR: 0	1.19	1.19	1.19	1.19	1.16	1.16	1.16	1.00	1.11	1.11	1.11	1.06	1.06	1.06	1.02	1.02	1.02	1.00
1	1.13	1.11	1.08	1.06	1.11	1.08	1.06	.94	1.04	1.02	1.01	1.01	.99	.98	.97	.96	.95	.93
2	1.08	1.03	.99	.95	1.05	1.01	.97	.87	.98	.95	.92	.95	.92	.90	.92	.90	.88	.87
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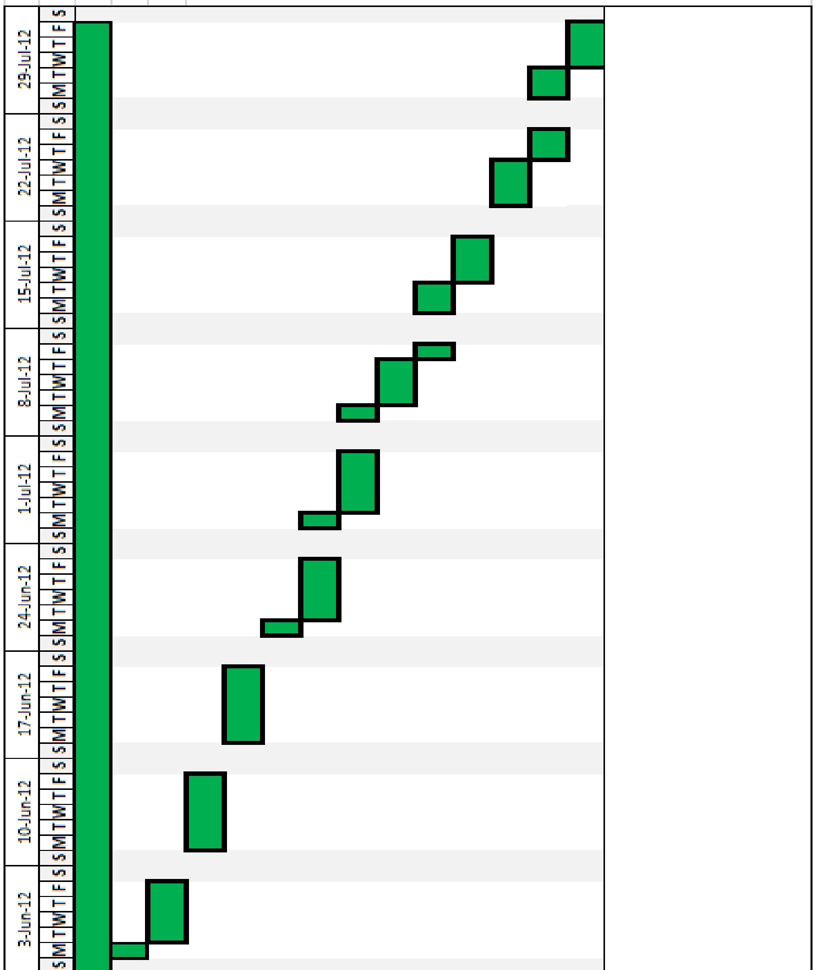
8	.80	.70	.64	.60	.79	.70	.64	.59	.69	.64	.60	.68	.63	.60	.67	.63	.59	.58
9	.76	.67	.61	.57	.75	.66	.60	.56	.65	.60	.56	.64	.60	.56	.63	.59	.56	.55
10	.73	.63	.57	.54	.72	.63	.57	.53	.62	.57	.53	.61	.56	.53	.60	.56	.53	.52

Appendix I: Construction Management Material

0	Task Name	Duration	Start	Finish
1	Steel Structure (Ground - 2nd Floor)	45 days	Mon 6/4/12	Fri 8/3/12
2	Shakeout	1 day	Mon 6/4/12	Mon 6/4/12
3	Erect Columns (Ground - 2nd Floor)	4 days	Tues 6/5/12	Fri 6/8/12
4	Erect Beams (1st Floor)	5 days	Mon 6/11/12	Fri 6/15/12
5	Erect Beams (2nd Floor)	5 days	Mon 6/18/12	Fri 6/22/12
6	Surveyors plumb up structure	1 day	Mon 6/25/12	Mon 6/25/12
7	Metal Decking (1st Floor)	5 days	Tues 6/26/12	Mon 7/2/12
8	Metal Decking (2nd Floor)	5 days	Tues 7/3/12	Mon 7/9/12
9	Detailing - Shear Studs	3 days	Tues 7/10/12	Thur 7/12/12
10	Detailing - Shear Studs	3 days	Thur 7/12/12	Mon 7/16/12
11	Edge Forms	3 days	Tues 7/17/12	Thur 7/19/12
12	WWF	3 days	Fri 7/20/12	Tues 7/24/12
13	Place Concrete	4 days	Wed 7/25/12	Mon 7/30/12
14	Finish Concrete	3 days	Tues 7/31/12	Thur 8/2/12



Appendix I: Construction Management Material