ARW ENGINEERS
structural consultants

Structural Calculations

For

Wolf Creek 500,000 Gal. Water Tank

Project Number: 16402

December 01, 2016

Prepared by
ARW Engineers
1594 West Park Circle
Ogden, Utah 84404

ARW ENGINEERS

Project No. 16402 Sheet No.

Project WOLF CREEK WATER TANK

Prepared By ZCH Date 11/16/2016

DESIGN CRITERIA

SOIL CRITERIA

AT-REST PRESSURE = 65 pcf (DOWNHILL SIDE)
95 pcf (UPHILL SIDE)

PASSIVE PRESSURE = 250 pcf

FRICTION = 0.35

SEISMIC AT-REST = 65 pcf + 7 pcf = 72 pcf (DOWNHILL SIDE)
95 pcf + 7 pcf = 102 pcf (UPHILL SIDE)

SEISMIC PASSIVE = 250 pcf - 22 pcf = 228 pcf

SOIL BEARING PRESSURE = 3,500 psf

SEISMIC CRITERIA

S_s = 0.92g F_a = 1.029 S_{MS} = 0.954g S_{DS} = 0.636g

S_1 = 0.31g F_v = 1.49 S_{M1} = 0.467g S_{D1} = 0.312g

SITE CLASS C

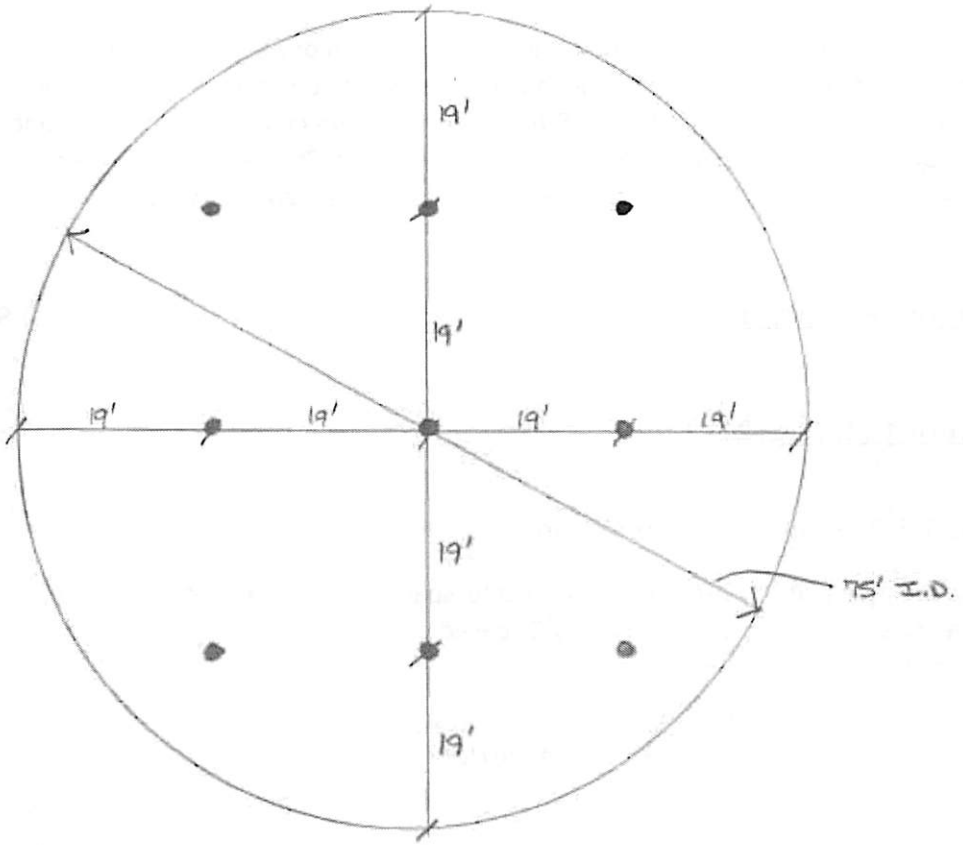
SNOW LOAD

ELEV. 5,600 FT (PER GOOGLE EARTH)

P_g = 82.0 psf

MAX SOIL COVER ON LID = 6" = 75 psf

TANK GEOMETRY



WALL HEIGHT = 16'-0"
WATER HEIGHT = 15'-5"

USGS Design Maps Detailed Report

2012/2015 International Building Code (41.3333°N, 111.825°W)

Site Class C – "Very Dense Soil and Soft Rock", Risk Category I/II/III

Section 1613.3.1 — Mapped acceleration parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2012/2015 International Building Code are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 1613.3.3.

From Figure 1613.3.1(1) [1] $S_S = 0.927$ g

From Figure 1613.3.1(2) [2] $S_1 = 0.315$ g

Section 1613.3.2 — Site class definitions

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class C, based on the site soil properties in accordance with Section 1613.

2010 ASCE-7 Standard – Table 20.3-1
SITE CLASS DEFINITIONS

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 1613.3.3 — Site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters

TABLE 1613.3.3(1)
VALUES OF SITE COEFFICIENT F_a

Site Class	Mapped Spectral Response Acceleration at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_S

For Site Class = C and S_S = 0.927 g, F_a = 1.029

TABLE 1613.3.3(2)
VALUES OF SITE COEFFICIENT F_v

Site Class	Mapped Spectral Response Acceleration at 1-s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = C and S_1 = 0.315 g, F_v = 1.485

Equation (16-37): $S_{MS} = F_a S_S = 1.029 \times 0.927 = 0.954$ g

Equation (16-38): $S_{M1} = F_v S_1 = 1.485 \times 0.315 = 0.467$ g

Section 1613.3.4 — Design spectral response acceleration parameters

Equation (16-39): $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 0.954 = 0.636$ g

Equation (16-40): $S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 0.467 = 0.312$ g

ENGINEERS

UTAH SNOW LOAD STUDY

Version Date July 20, 2012 author:TAB Reviewed by TMD

Project: Wolf Creek Water Tank

Description: Water Tank Lid Snow Load

Date: 11/16/2016

Job#: 16402

By: ZCH

County: Weber

Po:	43	psf
S:	63	psf/1000 ft.
A_o:	4.5	ft./1000
A:	5600	ft.

Pg: 81.6 psf

Table No. 1608.1.2 (b) REQUIRED SNOW LOADS FOR SELECTED UTAH CITIES AND TOWNS[1,2]

The following jurisdictions require design snow load values that differ from the equation in the Utah Snow Load Study

County	City	Elevation	Ground Snow Load (psf)	Roof Snow Load (psf)[6]
Carbon	Price[3]	5550	43	30
	All other County Locations[5]	-	-	-
Davis	Fruit Heights[3]	4500-4850	57	40
Emery	Green River[3]	4070	36	25
Garfield	Panguitch[3]	6600	43	30
Rich	Woodruff[3]	6315	57	40
	Laketown[4]	6000	57	40
	Garden City[5]	-	-	-
	Randolph[4]	6300	57	40
San Juan	Monticello[3]	6820	50	35
Summit	Coalville[3]	5600	86	60
	Kamas[4]	6500	114	80
Tooele	Tooele[3]	5100	43	30
Utah	Orem[3]	4650	43	30
	Pleasant Grove[4]	5000	43	30
	Provo[5]	-	-	-
Wasatch	Heber[5]	-	-	-
Washington	Leeds[3]	3460	29	20
	Santa Clara[3]	2850	21	15
	St. George[3]	2750	21	15
	All other County Locations[5]	-	-	-
Wayne	Loa[3]	7080	43	30

[1]The IBC Requires a minimum live load - See 1607.11.2

[2]This table is informational only in that actual site elevations may vary. Table is only valid if site elevation is within 100 feet of the listed elevation Otherwise contact the local Building Official

[3]Values adopted from table VII of the Utah Snow Load Study

[4]Values based on site-specific study. Contact local Building Official for additional information.

[5]Contact Local Building Official

[6]Based on C_e=1.0, C_t=1.0, and I_s=1.0

CONCRETE DEVELOPMENT AND LAP SPLICE DESIGN TABLE

BASED ON CHAPTER 12 OF THE 2011 ACI 318

Author: Matt McBride

Version June 17 2013

Concrete Properties

ψ_t = 1.0 For horizontal reinforcement placed such that more than 12 in of fresh concrete is cast below the development length or splice (i e Top Splice) = 1 3 - Otherwise = 1 0

ψ_e = 1.0 For Epoxy-coated bars or wires with cover less than 3db , or clear spacing less than 6db = 1 5 - For all other Epoxy-coated bars or wires = 1 2 -Otherwise = 1 0

λ = 1.0 When Light-weight Aggregate Concrete is used = 0 75 - Otherwise = 1 0

ψ_s = 1 0 For No 6 smaller bars and deformed wires = 0 8 - Otherwise = 1 0

Rebar Properties

fy = 60000 psi

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert Wall Bars, Fill on Metal Deck	NWC	3000 psi	17	22	8	22	29	8	28	36	10	33	43	12	48	62	13	55	72	15	62	81	17	69		19	76		30	96	38	124	49
Horiz. Wall Bars, Footing Top Bars	NWC	3000 psi	17	22	8	22	29	8	28	36	10	33	43	12	48	62	13	55	72	15	62	81	17	69		19	76		30	96	38	124	49
Beam Bottom Bars, Column Bars	NWC	3000 psi	17	22	8	22	29	11	28	36	14	33	43	16	48	62	19	55	72	22	62	81	25	69		27	76		30	96	38	124	49
Footing Bottom Bars	NWC	3000 psi	12	16	8	14	18	8	17	22	10	20	26	12	29	38	13	33	43	15	37	48	17	42		19	46		30				
Beam Top Bars	NWC	3000 psi	22	29	8	29	38	11	36	47	14	43	56	16	63	82	19	72	94	22	81	105	25	90		27	98		30	125	38	161	49
Slab on Grade	NWC	3000 psi	12	16	8	14	18	8	17	22	10	20	26	12	32	42	13	42	55	15	53	69	17	69		19	76		30				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert Wall Bars, Fill on Metal Deck	NWC	4000 psi	15	20	7	19	25	7	24	31	8	29	38	10	42	55	12	48	62	13	54	70	15	60		17	66		26	84	33	107	43
Horiz. Wall Bars, Footing Top Bars	NWC	4000 psi	15	20	7	19	25	7	24	31	8	29	38	10	42	55	12	48	62	13	54	70	15	60		17	66		26	84	33	107	43
Beam Bottom Bars, Column Bars	NWC	4000 psi	15	20	7	19	25	9	24	31	12	29	38	14	42	55	17	48	62	19	54	70	21	60		24	66		26	84	33	107	43
Footing Bottom Bars	NWC	4000 psi	12	16	7	12	16	7	15	20	8	18	23	10	25	33	12	29	38	13	33	43	15	36		17	40		26				
Beam Top Bars	NWC	4000 psi	19	25	7	25	33	9	31	40	12	37	48	14	54	70	17	62	81	19	70	91	21	78		24	85		26	108	33	139	43
Slab on Grade	NWC	4000 psi	12	16	7	12	16	7	15	20	8	18	23	10	28	36	12	36	47	13	46	60	15	60		17	66		26				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert Wall Bars, Fill on Metal Deck	NWC	4500 psi	14	18	7	18	23	6	23	30	8	27	35	9	40	52	11	45	59	13	51	66	14	56		16	62		25	79	31	101	40
Horiz Wall Bars, Footing Top Bars	NWC	4500 psi	14	18	7	18	23	6	23	30	8	27	35	9	40	52	11	45	59	13	51	66	14	56		16	62		25	79	31	101	40
Beam Bottom Bars, Column Bars	NWC	4500 psi	14	18	7	18	23	9	23	30	11	27	35	13	40	52	16	45	59	18	51	66	20	56		22	62		25	79	31	101	40
Footing Bottom Bars	NWC	4500 psi	12	16	7	12	16	6	14	18	8	17	22	9	24	31	11	27	35	13	31	40	14	34		16	37		25				
Beam Top Bars	NWC	4500 psi	18	23	7	24	31	9	30	39	11	35	46	13	51	66	16	59	77	18	66	86	20	73		22	80		25	102	31	131	40
Slab on Grade	NWC	4500 psi	12	16	7	12	16	6	14	18	8	17	22	9	27	35	11	34	44	13	44	57	14	56		16	62		25				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert Wall Bars, Fill on Metal Deck	NWC	5000 psi	13	17	6	17	22	6	22	29	7	26	34	9	38	49	10	43	56	12	48		13	54		15	59		23	75	30	96	38
Horiz. Wall Bars, Footing Top Bars	NWC	5000 psi	13	17	6	17	22	6	22	29	7	26	34	9	38	49	10	43	56	12	48		13	54		15	59		23	75	30	96	38
Beam Bottom Bars, Column Bars	NWC	5000 psi	13	17	6	17	22	8	22	29	11	26	34	13	38	49	15	43	56	17	48		19	54		21	59		23	75	30	96	38
Footing Bottom Bars	NWC	5000 psi	12	16	6	12	16	6	13	17	7	16	21	9	23	30	10	26	34	12	29		13	32		15	36		23				
Beam Top Bars	NWC	5000 psi	17	22	6	23	30	8	28	36	11	34	44	13	49	64	15	56	73	17	63		19	69		21	76		23	97	30	125	38
Slab on Grade	NWC	5000 psi	12	16	6	12	16	6	13	17	7	16	21	9	25	33	10	32	42	12	41		13	54		15	59		23				

CONCRETE DEVELOPMENT AND LAP SPLICE DESIGN TABLE

BASED ON CHAPTER 12 OF THE 2011 ACI 318

Author Matt McBride

Version June 17 2013

Concrete Properties

ψ_t = 1.3 For horizontal reinforcement placed such that more than 12 in of fresh concrete is cast below the development length or splice (i e Top Splice) = 1.3 - Otherwise = 1.0

ψ_e = 1.0 For Epoxy-coated bars or wires with cover less than 3db , or clear spacing less than 6db = 1.5 - For all other Epoxy-coated bars or wires = 1.2 -Otherwise = 1.0

λ = 1.0 When Light-weight Aggregate Concrete is used = 0.75 - Otherwise = 1.0

ψ_s = 1.0 For No. 6 smaller bars and deformed wires = 0.8 - Otherwise = 1.0

Rebar Properties

fy = 60000 psi

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS																																	
Bar Location	Concrete		BAR SIZE																														
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert. Wall Bars, Fill on Metal Deck	NWC	3000 psi	22	29	8	29	38	8	36	47	10	43	56	12	63	82	13	72	94	15	81	105	17	90		19	98		30	125	38	161	49
Horiz. Wall Bars, Footing Top Bars	NWC	3000 psi	22	29	8	29	38	8	36	47	10	43	56	12	63	82	13	72	94	15	81	105	17	90		19	98		30	125	38	161	49
Beam Bottom Bars, Column Bars	NWC	3000 psi	22	29	8	29	38	11	36	47	14	43	56	16	63	82	19	72	94	22	81	105	25	90		27	98		30	125	38	161	49
Footing Bottom Bars	NWC	3000 psi	13	17	8	18	23	8	22	29	10	26	34	12	38	49	13	43	56	15	49	64	17	54		19	59		30				
Beam Top Bars	NWC	3000 psi	28	36	8	38	49	11	47	61	14	56	73	16	81	105	19	93	121	22	105	137	25	116		27	128		30	162	38	209	49
Slab on Grade	NWC	3000 psi	13	17	8	18	23	8	22	29	10	26	34	12	42	55	13	54	70	15	69	90	17	90		19	98		30				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS																																	
Bar Location	Concrete		BAR SIZE																														
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert. Wall Bars, Fill on Metal Deck	NWC	4000 psi	19	25	7	25	33	7	31	40	8	37	48	10	54	70	12	62	81	13	70	91	15	78		17	85		26	108	33	139	43
Horiz. Wall Bars, Footing Top Bars	NWC	4000 psi	19	25	7	25	33	7	31	40	8	37	48	10	54	70	12	62	81	13	70	91	15	78		17	85		26	108	33	139	43
Beam Bottom Bars, Column Bars	NWC	4000 psi	19	25	7	25	33	9	31	40	12	37	48	14	54	70	17	62	81	19	70	91	21	78		24	85		26	108	33	139	43
Footing Bottom Bars	NWC	4000 psi	12	16	7	15	20	7	19	25	8	23	30	10	33	43	12	37	48	13	42	55	15	47		17	51		26				
Beam Top Bars	NWC	4000 psi	25	33	7	33	43	9	41	53	12	49	64	14	71	92	17	81	105	19	91	118	21	101		24	111		26	141	33	181	43
Slab on Grade	NWC	4000 psi	12	16	7	15	20	7	19	25	8	23	30	10	36	47	12	47	61	13	60	78	15	78		17	85		26				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert. Wall Bars, Fill on Metal Deck	NWC	4500 psi	18	23	7	24	31	6	30	39	8	35	46	9	51	66	11	59	77	13	66	86	14	73		16	80		25	102	31	131	40
Horiz. Wall Bars, Footing Top Bars	NWC	4500 psi	18	23	7	24	31	6	30	39	8	35	46	9	51	66	11	59	77	13	66	86	14	73		16	80		25	102	31	131	40
Beam Bottom Bars, Column Bars	NWC	4500 psi	16	23	7	24	31	9	30	39	11	35	46	13	51	66	16	59	77	18	66	86	20	73		22	80		25	102	31	131	40
Footing Bottom Bars	NWC	4500 psi	12	16	7	14	18	6	18	23	8	21	27	9	31	40	11	35	46	13	40	52	14	44		16	48		25				
Beam Top Bars	NWC	4500 psi	23	30	7	31	40	9	38	49	11	46	60	13	67	87	16	76	99	18	86	112	20	95		22	104		25	133	31	171	40
Slab on Grade	NWC	4500 psi	12	16	7	14	18	6	18	23	8	21	27	9	34	44	11	44	57	13	57	74	14	73		16	80		25				

CONCRETE REINFORCING DEVELOPMENT & SPLICE LENGTHS

Bar Location	Concrete		BAR SIZE																													
	Type	Strength	#3			#4			#5			#6			#7			#8			#9			#10			#11			#14		#18	
			l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_s	l_{dh}	l_d	l_{dh}	l_d	l_{dh}
Vert. Wall Bars, Fill on Metal Deck	NWC	5000 psi	17	22	6	23	30	6	28	36	7	34	44	9	49	64	10	56	73	12	63		13	69		15	76		23	97	30	125	38
Horiz. Wall Bars, Footing Top Bars	NWC	5000 psi	17	22	6	23	30	6	28	36	7	34	44	9	49	64	10	56	73	12	63		13	69		15	76		23	97	30	125	38
Beam Bottom Bars, Column Bars	NWC	5000 psi	17	22	6	23	30	8	28	36	11	34	44	13	49	64	15	56	73	17	63		19	69		21	76		23	97	30	125	38
Footing Bottom Bars	NWC	5000 psi	12	16	6	14	18	6	17	22	7	20	26	9	29	38	10	34	44	12	38		13	42		15	46		23				
Beam Top Bars	NWC	5000 psi	22	29	6	29	38	8	36	47	11	44	57	13	63	82	15	72	94	17	61		19	90		21	99		23	126	30	162	38
Slab on Grade	NWC	5000 psi	12	16	6	14	18	6	17	22	7	20	26	9	33	43	10	42	55	12	54		13	69		15	76		23				

ENVIRONMENTAL FACTOR

ACI 350.6 SEC. 9.2.6

WATER COMBINATIONS $\Rightarrow$ $\gamma = 1.6$

$$S_d = \frac{0.9(60{,}000)}{1.6(20{,}000)} = 1.69$$

SOIL COMBINATIONS $\Rightarrow$ $\gamma = 1.4$

$$S_d = \frac{0.9(60{,}000)}{1.4(20{,}000)} = 1.93$$

HOOP AND TENSILE STRESS ONLY

FLEXURAL STRESS

$f_s = 20{,}000$ psi (CONSERVATIVE)

$\therefore S_d = 1.93$

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Project # 16402
Prepared By ZCH
Date 11/16/2016

Program Authors TAB & DOC
Last Revised 10/20/2010
Reviewed By TAB

ENGINEERS

Circular Concrete Tanks without Prestressing

(Based on the 1993 PCA Document)

Design Criteria

f'c	4500	psi
D_{tank}	75	ft
H_{tank}	16	ft
t_{wall}	12	in
Fluid Pressure	62.4	pcf
Soil Pressure	102	pcf
E_s	29000000	psi
E_c	3823676.24	psi
n	7.6	
Surcharge	157	psf
Soil on Lid	0.5	ft
Load Factor		
$F_{liquid\ pressure}$	1.4	
$F_{Soil\ pressure}$	1.6	
Environmental		
Durability Factor		
Flexure (liquid)	1.93	
Tension (liquid)	1.93	
Flexure (soil)	1.69	
Compression (soil)	1	
H^2/Dt	3.41	

SEISMIC ACTIVE

Estimation of Tank Wall Thickness

Limit Ring Tension Stress in Concrete Wall from 7% to 12% of f'c

For given t and H^2/Dt, with a hinged base/free top (Table A-5)

Max Coefficient= 0.611 (Table A-5)

w_u	169	pcf
T_{max}	61765	lbs.
$T_{unfactored}$	22859	lbs.
$A_{s(req'd)}$	1.14	in^2
$A_{s(used)}$	1.2	in^2
	OK	

Compression Check	
F'c	869
0.33f'c	1485
OK	

$F_{t(conc)}$ 217 psi

This equates to 4.83 % of f'c
Wall thickness is OK

The Following Load Cases were used in Analysis:

Load Case #1: Full of Water, No Lid, No Backfill
Load Case #2: Empty, No Lid, w/Backfill
Load Case #3: Empty, w/Lid, w/Backfill
Load Case #4: Full of Water, w/Lid, Ignore Backfill

Load Case #1-Full of Water, No Lid, No Backfill

Assume Free Top/Hinged Base (Tables A-5 and A-7)
Effects of Possible outward movement will be handled by designing the entire portion of the wall for the maximum Ring Tension and Moment

Ring Force=(A-5 Coef.)w_uHR w_uHR= 101162.88

Moment =(A-7 Coef.)w_uH^3 w_uH^3= 690605.2608

	A-5 Coef.	RF (#)	A-7 Coef.	Moment (#-ft/ft)
Top	-0.004	-380	0	0
0.1H	0.118	11928	0.0000	12
0.2H	0.238	24082	0.0002	139
0.3H	0.358	36203	0.0008	532
0.4H	0.469	47445	0.0019	1304
0.5H	0.559	56562	0.0038	2618
0.6H	0.611	61765	0.0061	4241
0.7H	0.597	60394	0.0085	5865
0.8H	0.493	49923	0.0098	6773
0.9H	0.288	29089	0.0080	5551
Bottom	0.000	0	0	0

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Load Case #2-Empty, No Lid, w/ Backfill

Use Durability Coefficients as Noted Previous

Soil Over Lid= 0.5 ft
p 78 5

Ring Force=(A-5 Coef)w_oHR+(A-6 Coef)pR

w_oHR= -188986

pR= -9090.3

Moment=(A-7 Coef)($w_o h^3$+ph^2)

$w_o h^3$+ph^2 = -1184049

	A-5 Coef	RF (#)	A-6 Coef.	RF (#)	Total RF (#)	A-7 Coef.	Moment (#-ft/ft)
Top	-0 004	710	0 996	-9056.168496	-8347	0	0
0.1H	0.118	-22282	1 018	-9253 067825	-31536	0 0000	-20
0.2H	0.238	-44989	1 038	-9436 245945	-54426	0 0002	-239
0.3H	0 358	-67632	1.058	-9616 336794	-77248	0 0008	-911
0.4H	0 469	-88634	1.069	-9717 5307	-98352	0 0019	-2236
0.5H	0 559	-105664	1 059	-9627 656791	-115292	0.0038	-4488
0.6H	0 611	-115385	1.011	-9186.176938	-124571	0 0061	-7272
0.7H	0 597	-112824	0.897	-8153 9991	-120978	0 0085	-10055
0.8H	0 493	-93263	0 693	-6304 037292	-99567	0.0098	-11613
0.9H	0.288	-54342	0 388	-3522 920038	-57865	0.0080	-9517
Bottom	0.000	0	0 000	0	0	0	0

Load Case #3-Empty, w/Lid, w/Backfill

Apply a shear force (V) @ top of wall to make Ring Tension = 0 @ top of Wall

When top of tank is free, Ring Force (LC#2) = -8347 #

At top of wall (0.0H) from table A-8, Coefficient= -8 07 #

Therefore, the shear force (V) required to produce zero ring force at the top of the tank=
(Coef A-8 @ 0 0H)(VR/H)=(Ring Force from LC#2)

Therefore

V= -441 #
VR/H= -1034 #

$Delta_{RF}$=Change in Ring Force Due to V applied @ the top of wall

$Delta_{RF}$=(A-8 Coef)(VR/H)

Find the change in moment ($Delta_{mom}$) due to the V applied @ top

If S_D for moment is less than S_D for compression, then V is reduced by (S_{bal}/S_{DC})

$Delta_{mom}$=(A-9 Coef)VH

VH= -7060

	A-8 Coef.	$Delta_{RF}$ (#)	LC#2 RF (#)	Total RF (#)	A-9 Coef.	$Delta_{mom}$ (#-ft/ft)	LC #2 Moment (#-ft/ft)	Total Moment (#-ft/ft)
Top	-8 071	8347	-8347	0	0	0	0	0
0.1H	-4 946	5115	-31536	-26421	0 0647	-457	-20	-477
0.2H	-2 475	2560	-54426	-51865	0.0797	-563	-239	-802
0.3H	-0 843	871	-77248	-76377	0.0694	-490	-911	-1401
0.4H	0 059	-61	-98352	-98413	0 0497	-351	-2236	-2587
0.5H	0.434	-449	-115292	-115741	0 0305	-216	-4488	-4704
0.6H	0 480	-496	-124571	-125067	0.0150	-106	-7272	-7378
0.7H	0 363	-376	-120978	-121354	0.0042	-30	-10055	-10085
0.8H	0 198	-205	-99567	-99772	-0 0027	19	-11613	-11594
0.9H	0.060	-62	-57865	-57927	-0 0075	53	-9517	-9464
Bottom	0 000	0	0	0	-0 0124	87	0	87

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Load Case #4-Full of Water, w/Lid, ignore Backfill

Add the effects of shear @ the top of the tank to LC #1

At the top of the wall - Coefficient from Table A-8= -8.07 #

(Coef A-8 @ 0 0H)(VR/H) = (Ring Force from LC#1)

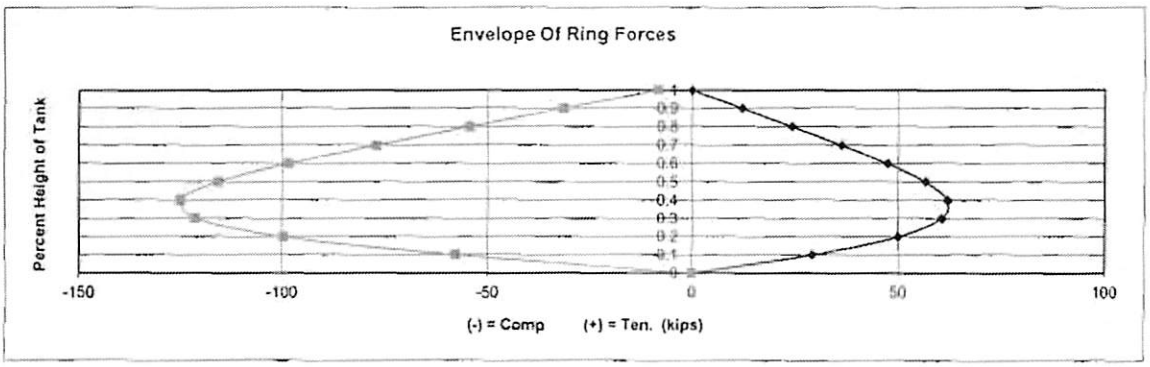
V= -20 #
VR/H= -47 # (For Ring Force)
VH= -321 # (For Moment)

	A-8 Coef.	$Delta_{RF}$ (#)	LC#1 RF (#)	Total RF (#)	A-9 Coef.	$Delta_{mom}$ (#-ft/ft)	LC#1 Moment (#-ft/ft)	Total Moment (#-ft/ft)
Top	-8.07	380	-380	0	0	0	0	0
0.1H	-4.95	233	11928	12160	0 065	-21	12	-9
0.2H	-2 48	117	24082	24199	0.080	-26	139	114
0.3H	-0 84	40	36203	36243	0.069	-22	532	509
0.4H	0.06	-3	47445	47443	0 050	-16	1304	1288
0.5H	0 43	-20	56562	56541	0 031	-10	2618	2608
0.6H	0 48	-23	61765	61742	0 015	-5	4241	4237
0.7H	0.36	-17	60394	60377	0.004	-1	5865	5864
0.8H	0 20	-9	49923	49914	-0 003	1	6773	6774
0.9H	0 06	-3	29089	29086	-0 008	2	5551	5553
Bottom	0	0	0	0	-0.012	4	0	4

Envelope of Ring Forces

	LC#1	LC#2	LC#3	LC#4	Max	Min
Top	-380	-8347	0	0	0	-8347
0.1H	11928	-31536	-26421	12160	12160	-31536
0.2H	24082	-54426	-51865	24199	24199	-54426
0.3H	36203	-77248	-76377	36243	36243	-77248
0.4H	47445	-98352	-98413	47443	47445	-98413
0.5H	56562	-115292	-115741	56541	56562	-115741
0.6H	61765	-124571	-125067	61742	61765	-125067
0.7H	60394	-120978	-121354	60377	60394	-121354
0.8H	49923	-99567	-99772	49914	49923	-99772
0.9H	29089	-57865	-57927	29086	29089	-57927
Bottom	0	0	0	0	0	0

	Tension	Compression
Bottom	0	0
0.9H	29	-58
0.8H	50	-100
0.7H	60	-121
0.6H	62	-125
0.5H	57	-116
0.4H	47	-98
0.3H	36	-77
0.2H	24	-54
0.1H	12	-32
Top	0	-8



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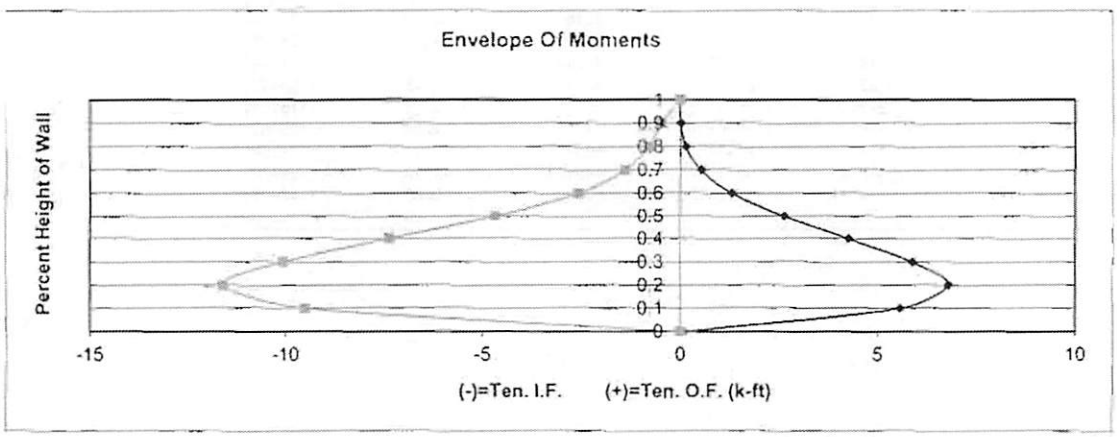
Envelope of Moments

	LC#1	LC#2	LC#3	LC#4	Max	Min
Top	0	0	0	0	0	0
0.1H	12	-20	-477	-9	12	-477
0.2H	139	-239	-802	114	139	-802
0.3H	532	-911	-1401	509	532	-1401
0.4H	1304	-2236	-2587	1288	1304	-2587
0.5H	2618	-4488	-4704	2608	2618	-4704
0.6H	4241	-7272	-7378	4237	4241	-7378
0.7H	5865	-10055	-10085	5864	5865	-10085
0.8H	6773	-11613	-11594	6774	6774	-11613
0.9H	5551	-9517	-9464	5553	5553	-9517
Bottom	0	0	87	4	87	0

	Tension O.F.	Tension I.F.
Bottom	0	0
0.9H	6	-10
0.8H	7	-12
0.7H	6	-10
0.6H	4	-7
0.5H	3	-5
0.4H	1	-3
0.3H	1	-1
0.2H	0	-1
0.1H	0	0
Top	0	0



WALL DESIGN

* SEE SPREADSHEET FOR MAX TENSION AND COMPRESSION CHECK

RING STEEL (HORIZONTAL BARS)

MAX RING FORCE ⇒ 62 K @ 0.6(16') = 9.6' FROM TOP

UP TO 10' WALL ∴ USE (2) #7 @ 12" O.C. (SEE SPREADSHEET) A_s = 1.20 in²

TOP 6' OF WALL ⇒ T = 47 K

$$A_{s\,req'd} = \frac{47.0K}{0.9(60ksi)} = 0.87\ in^2/ft$$

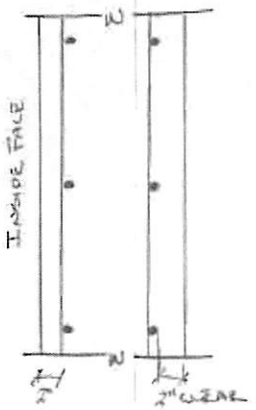
∴ USE (2) #6 @ 12" O.C. (0.88 in²/ft)

CHECK MIN. SHRINKAGE STEEL:

$$A_{s\,min} = 0.005(12")(12") = 0.72\ in^2/ft$$

∴ USE #6 @ 12" O.C.

MOMENT REINF. (VERT. BARS)



MAX MOMENT ⇒ TENSION INSIDE FACE = 12 K-FT-FT

TENSION OUTSIDE FACE = 7 K-FT-FT

f'_c = 4,500 psi

d = 9.5 in (INSIDE)
= 8.5 in (OUTSIDE)

b = 12 in

TEMP STEEL = 0.003

$A_{s\,min} = 0.003(12")(12") = 0.43\ in^2/ft$ (BOTH FACE)

FLEXURE $A_{s\,min}$ ⇒

$$A_{s\,min} = \frac{3\sqrt{4,500}}{60,000}(12")(9.5") = 0.38\ in^2/ft$$ (ONE FACE)

∴ USE #6 @ 12" O.C. EA. FACE

INSIDE FACE:

$$\frac{M_u}{\phi b d^2} = \frac{12,000\,lb\text{-}ft(12")}{0.9(12")(9.5")^2} = 148$$

$$\rho = \frac{0.85(4.5)}{60}\left(1 - \sqrt{1 - \frac{2(148)}{0.85(4,500)}}\right)$$

ρ = 0.0025 A_s = 12"(9.5")(0.0025)

A_s = 0.28 in²/ft

OUTSIDE FACE:

$$\frac{7,000\,lb\text{-}ft(12")}{0.9(12")(8.5")^2} = 107$$

$$\rho = \frac{0.85(4.5)}{60}\left(1 - \sqrt{1 - \frac{2(107)}{0.85(4,500)}}\right)$$

ρ = 0.0018

∴ FLEXURE MIN. CONTROLS

WALL DESIGN (CONT'D)

SHEAR STRENGTH OF WALL

WALL CAPACITY $\Rightarrow$ $\phi V_c = 0.75(2)\sqrt{4,500}\,(12.in)(8.5in) = 10.3K$

$\phi V_c = 10.3K$

V_{MAX} IN WALL $\Rightarrow$ $H^2/DE = 3.41$

COEFF = 0.158 (PCA TABLE A-12)

$V = 0.158(102pcf)(16)^2(1.6) = 6.6K < 10.3K$ ✓ ADEQUATE

ARW ENGINEERS
structural consultants

Project No. 16402 Sheet No.

Project Wolf Creek Water Tank

Prepared By ZCH Date 11/16/2016

Tank Lid Design

Snow Load = 82 psf

DL = 150 pcf (8"/12) + 15 psf + 75 psf (soil) = 190 psf

USE 8" LID - SEE SPREADSHEET FOR CALCS

TEMP. SHRINKAGE STEEL => $A_{s\,min} = 12"(5")(0.005) = 0.48\ in^2$

@ A MIN. #5 @ 12" O.C. TOP AND BOTTOM.

FLEXURE MIN. =>

ENGINEERS

Concrete Water Tank - Roof Design

11/17/2016
11:49:42 AM

Version Date: 10/28/10 Author TAB
Job Title Wolf Creek Water Tank Job # 16402

Roof Slab Design

Min Thickness

Slab Span	18.75 ft	Est. Column Thickness		14 in
h_{min}	6.39 in			
Use Slab Thickness	8 in		d	5.5 in
f'c	4500 psi		fy	60 ksi

Loads

Dead Load	115 psf
Live Load	0 psf
Soil Load	75 psf
Snow Load	82 psf
W_U	359.2 psf

Shear Capacity of Slab

Round Column Dim	14 in	
b_o	61.2611 in	
V_U	126.281 kips	
φV_C (No Drop Panel)	67.807 kips	NG Use Drop Panel
Drop Panel Dimension	4 ft square	
New b_o	214 in	
φV_C Drop Panel	236.867 kips	Ok
Drop Panel Thickness	4 in	
b_o	73.8274 in	
φV_C	141.146 kips	Ok

Flexural Design by Direct Design Method Of ACI 318

l_2	17.667 ft	S_d	1.93
l_n	16.5003 ft	Strip Width	8.833 ft
M_o	215.971 K-ft		
Exterior Span M^+ factor	0.63	Exterior M^+ factored Moment	136.06 k-ft
Exterior Span M^- factor	0.75	Exterior M^- factored Moment	161.98 k-ft
Interior Span M^+ factor	0.35	Interior M^+ factored Moment	75.59 k-ft
Interior Span M^- factor	0.65	Interior M^- factored Moment	140.38 k-ft

Col Strip Factored Mom.		Mid Strip Factored Mom
M^+	0.6	0.4
Exterior M^-	0.75	0.25
Interior M^-	0.75	0.25

Exterior Positive Moment

Column Strip	157.559 k-ft	Middle Strip	105.04 k-ft
Moment per foot of width	17.8376 k-ft/ft	Moment per foot of width	11.892 k-ft/ft
Mu/φ	19.8195 k-ft/ft	Mu/φ	13.213 k-ft/ft
Mu/φ	237.834 k-in/ft	Mu/φ	158.56 k-in/ft
As	0.79601 in^2	As	0.5116 in^2
a	1.04053	a	0.6687
#4 Bar Spacing	3.02 in oc	#4 Bar Spacing	4.69 in oc
#5 Bar Spacing	4.67 in oc	#5 Bar Spacing	7.27 in oc
#6 Bar Spacing	6.63 in oc	#6 Bar Spacing	10.32 in oc
#7 Bar Spacing	9.05 in oc	#7 Bar Spacing	14.07 in oc
#8 Bar Spacing	11.91 in oc	#8 Bar Spacing	18.53 in oc

Exterior Negative Moment

Enter new d for Col strip	9.5		
Column Strip	234.463 k-ft	Middle Strip	78.154 k-ft
Moment per foot of width	26.544 k-ft/ft	Moment per foot of width	8.848 k-ft/ft
Mu/φ	29.4933 k-ft/ft	Mu/φ	9.8311 k-ft/ft
Mu/φ	353.92 k-in/ft	Mu/φ	117.97 k-in/ft
As	0.64998 in^2	As	0.3741 in^2
a	0.84964	a	0.4891
#4 Bar Spacing	3.69 in oc	#4 Bar Spacing	6.41 in oc
#5 Bar Spacing	5.72 in oc	#5 Bar Spacing	9.94 in oc
#6 Bar Spacing	8.12 in oc	#6 Bar Spacing	14.11 in oc
#7 Bar Spacing	11.08 in oc	#7 Bar Spacing	19.24 in oc
#8 Bar Spacing	14.59 in oc	#8 Bar Spacing	25.34 in oc

Interior Positive Moment

Column Strip	87.5329	k-ft	Middle Strip	58.355	k-ft
Moment per foot of width	9.90976	k-ft/ft	Moment per foot of width	6.6065	k-ft/ft
Mu/φ	11.0108	k-ft/ft	Mu/φ	7.3406	k-ft/ft
Mu/φ	132.13	k-in/ft	Mu/φ	88.087	k-in/ft
As	0.42151	in^2	As	0.276	in^2
a	0.55099		a	0.3608	
#4 Bar Spacing	5.69	in oc	#4 Bar Spacing	8.70	in oc
#5 Bar Spacing	8.83	in oc	#5 Bar Spacing	13.48	in oc
#6 Bar Spacing	12.53	in oc	#6 Bar Spacing	19.13	in oc
#7 Bar Spacing	17.08	in oc	#7 Bar Spacing	26.09	in oc
#8 Bar Spacing	22.49	in oc	#8 Bar Spacing	34.35	in oc

Interior Negative Moment

Enter new d for Col strip	9.5	in			
Column Strip	203.201	k-ft	Middle Strip	67.734	k-ft
Moment per foot of width	23.0048	k-ft/ft	Moment per foot of width	7.6683	k-ft/ft
Mu/φ	25.5609	k-ft/ft	Mu/φ	8.5203	k-ft/ft
Mu/φ	306.731	k-in/ft	Mu/φ	102.24	k-in/ft
As	0.55967	in^2	As	0.3222	in^2
a	0.7316		a	0.4211	
#4 Bar Spacing	4.29	in oc	#4 Bar Spacing	7.45	in oc
#5 Bar Spacing	6.65	in oc	#5 Bar Spacing	11.55	in oc
#6 Bar Spacing	9.43	in oc	#6 Bar Spacing	16.39	in oc
#7 Bar Spacing	12.86	in oc	#7 Bar Spacing	22.35	in oc
#8 Bar Spacing	16.94	in oc	#8 Bar Spacing	29.43	in oc

How Far past support must negative moment reinf. Extend?

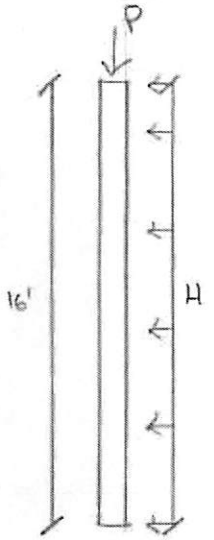
Column Strip	5.44511	ft	Use	6 ft
Middle Strip	3.63007	ft	Use	4 ft

Column Design

$DL = 115 psf (18.75')^2 (1.32)(1 + 0.2(0.64)) = 60.2K$ (0.2 S_{DS})

$SL = 82 psf (18.75')^2 (1.32) = 38K$

$Soil = 75 psf (18.75')^2 (1.32) = 34.8K$



$H = \pi (1.25^2)(62.4pcf)(7''/12)^2 + 0.4(0.64)(1.25)(1.2')^2(150pcf) = 149 plf$

USE 16"Ø column w/ (8) #5 bars

Find Transverse Reinf. ⇒ ACI 350 CH 21.4.4

$\rho_s = 0.12(4.5)/60ksi = 0.009$

Spacing = 16"/4 = 4"

6(5/8) = 3.75"

Per 10.9.3

ρ_s ⇒ $A_g = \pi(16)^2/4 = 201 in^2$

$A_c = \pi(12)^2/4 = 113 in^2$

$\rho_s = 0.45\left(\frac{201}{113} - 1\right)\frac{4.5}{60} = 0.026$ ✓ controls

Req'd Pitch #4 ties = $0.026 = \frac{0.20(\pi)(12.5in)}{113(s)} = 2.7in$ $S_{Req'd} = 2.5"$

Spacing of #3 Hoops = $0.009 = \frac{0.11(\pi)(12.625in)}{113(s)} = 4.2in$ $S_{Req'd} = 4"$

USE #4 spiral ties @ 2.5" pitch

OR #3 Hoops @ 3" o.c.

Concrete Column

Description : 14" Square Concrete Column

Code References

Calculations per ACI 318-11, IBC 2012, CBC 2013, ASCE 7-10
Load Combinations Used : ASCE 7-10

General Information

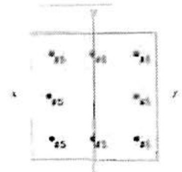
f'c : Concrete 28 day strength	=	4.50 ksi
E =	=	3,823.68 ksi
Density	=	150.0 pcf
β	=	0.8250
fy - Main Rebar	=	60.0 ksi
E - Main Rebar	=	29,000.0 ksi
Allow. Reinforcing Limits		ASTM A615 Bars Used
Min. Reinf.	=	1.0 %
Max. Reinf.	=	8.0 %

Overall Column Height = 17.0 ft
End Fixity: Top & Bottom Pinned
Brace condition for deflection (buckling) along columns :
X-X (width) axis :
Unbraced Length for X-X Axis buckling = 17.0 ft, K = 1.0
Y-Y (depth) axis :
Unbraced Length for X-X Axis buckling = 17.0 ft, K = 1.0

Column Cross Section

Column Dimensions : 14.0in Square Column, Column Edge to Rebar Edge Cover = 2.0in

Column Reinforcing : 4 - #5 bars @ corners,, 1 - #5 bars top & bottom between corner bars, 1 - #5 bars left & right between corner bars



Applied Loads

Entered loads are factored per load combinations specified by user

Column self weight included : 3,470.83 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 17.0 ft above base, Xecc = 3.0in, Yecc = 3.0in, D = 60.20, S = 38.0, H = 35.0 k
BENDING LOADS . . .
Lat. Uniform Load creating Mx-x, E = 0.1490 k/ft

DESIGN SUMMARY

Load Combination: +1.20D+1.60S+1.60H
Location of max.above base: 16.886 ft

Maximum Stress Ratio 0.808 : 1
Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	193.205 k	φ * Pn =	237.843 k
Mu-x =	-47.260 k-ft	φ * Mn-x =	-58.324 k-ft
Mu-y =	47.260 k-ft	φ * Mn-y =	58.688 k-ft
Mu Angle =	45.0 deg		
Mu at Angle =	66.836 k-ft	φMn at Angle =	82.750 k-ft

Pn & Mn values located at Pu-Mu vector intersection with capacity curve

Column Capacities . . .

Pnmax : Nominal Max. Compressive Axial Capacity	889.01 k
Pnmin : Nominal Min. Tension Axial Capacity	-148.80 k
φ Pn, max : Usable Compressive Axial Capacity	462.287 k
φ Pn, min : Usable Tension Axial Capacity	-96.720 k

Maximum SERVICE Load Reactions . .

Top along Y-Y	1.959 k	Bottom along Y-Y	1.959 k
Top along X-X	2.484 k	Bottom along X-X	1.959 k

Maximum SERVICE Load Deflections . . .

Along Y-Y -0.08791 in at 9.926 ft above base
for load combination : +D+S+H
Along X-X 0.08701 in at 9.926 ft above base
for load combination : +D+S+H

General Section Information . φ = 0.650 β = 0.8250 θ = 0.80

ρ : % Reinforcing	1.265 %	Rebar % Ok
Reinforcing Area	2.480 in^2	
Concrete Area	196.0 in^2	

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	δx	δx * Mux	δY	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.40D+1.60H	Actual	Actual	16.83	125.??	240.87	1.000	35.0?	1.000	35.0?	45.000	47.5?	82.7?	0.400

Concrete Column

Description : 14" Square Concrete Column

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	δx	δx * Mux	δY	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.20D+1.60H	Actual	Actual	16.86	157.41	240.87	1.000	32.46	1.000	32.08	45.000	45.34	82.??	0.548
+1.20D+0.50S+1.60H	Actual	Actual	16.86	161.41	240.87	1.000	36.81	1.000	36.01	45.000	52.09	82.??	0.628
+1.20D+1.60S+1.60H	Actual	Actual	16.86	193.21	237.84	1.000	47.26	1.000	47.26	45.000	66.84	82.75	0.808
+1.20D+0.20S+E+1.60H	Actual	Actual	14.45	140.81	202.38	1.349	45.14	1.000	33.96	45.000	56.45	82.11	0.691
+0.90D+0.90H	Actual	Actual	16.89	88.85	243.12	1.000	21.40	1.000	21.42	45.000	30.29	82.??	0.366
+0.90D+E+0.90H	Actual	Actual	16.69	88.80	221.31	1.191	25.60	1.000	21.42	45.000	33.76	82.73	0.402

Maximum Reactions

Note : Only non-zero reactions are listed.

Load Combination	Reaction along X-X Axis @ Base	@ Top		Reaction along Y-Y Axis @ Base	@ Top	Axial Reaction @ Base
+D+H	1.400	1.400	k	1.400	1.400 k	98.671 k
+D+S+H	1.959	1.959	k	1.959	1.959 k	136.671 k
+D+0.750S+H	1.819	1.819	k	1.819	1.819 k	127.171 k
+D+0.70E+H	1.400	1.400	k	0.513	2.287 k	98.671 k
+D+0.750S+0.5250E+H	1.819	1.819	k	1.154	2.484 k	127.171 k
+0.60D+0.60H	0.840	0.840	k	0.840	0.840 k	59.203 k
+0.60D+0.70E+0.60H	0.840	0.840	k	0.047	1.727 k	59.203 k
D Only	0.885	0.885	k	0.885	0.885 k	63.671 k
S Only	0.559	0.559	k	0.558	0.559 k	38.000 k
E Only			k	1.387	1.287 k	k
H Only	0.515	0.515	k	0.515	0.515 k	35.000 k

Maximum Moments

Note : Only non-zero reactions are listed.

Load Combination	Moment About X-X Axis @ Base	@ Top		Moment About Y-Y Axis @ Base	@ Top	
+D+H		23.800	k-ft	23.800		k-ft
+D+S+H		33.300	k-ft	33.300		k-ft
+D+0.750S+H		30.925	k-ft	30.925		k-ft
+D+0.70E+H		23.800	k-ft	23.800		k-ft
+D+0.750S+0.5250E+H		30.925	k-ft	30.925		k-ft
+0.60D+0.60H		14.280	k-ft	14.280		k-ft
+0.60D+0.70E+0.60H		14.280	k-ft	14.280		k-ft
D Only		15.050	k-ft	15.050		k-ft
S Only		9.500	k-ft	9.500		k-ft
E Only			k-ft			k-ft
H Only		8.750	k-ft	8.750		k-ft

Maximum Deflections for Load Combinations

Load Combination	Max. X-X Deflection		Distance		Max. Y-Y Deflection		Distance	
+D+H	0.0628	in	9.926	ft	-0.063	in	9.926	ft
+D+S+H	0.0879	in	9.926	ft	-0.088	in	9.926	ft
+D+0.750S+H	0.0816	in	9.926	ft	-0.082	in	9.926	ft
+D+0.70E+H	0.0628	in	9.926	ft	-0.047	in	10.383	ft
+D+0.750S+0.5250E+H	0.0816	in	9.926	ft	-0.070	in	10.154	ft
+0.60D+0.60H	0.0377	in	9.926	ft	-0.038	in	9.926	ft
+0.60D+0.70E+0.60H	0.0377	in	9.926	ft	-0.022	in	10.839	ft
D Only	0.0397	in	9.926	ft	-0.040	in	9.926	ft
S Only	0.0251	in	9.926	ft	-0.025	in	9.926	ft
E Only	0.0000	in	0.000	ft	0.023	in	8.557	ft
H Only	0.0231	in	9.926	ft	-0.023	in	9.926	ft

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Project Descr:

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Concrete Column

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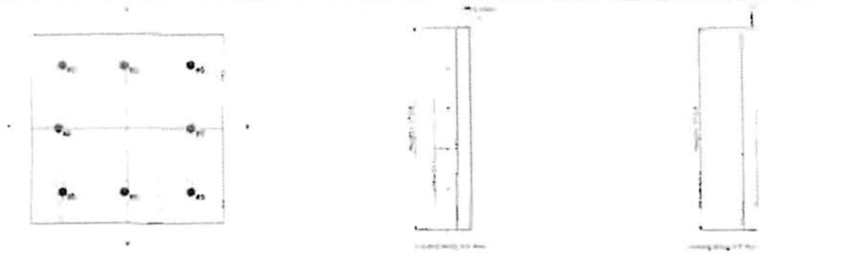
ENERCALC, INC. 1983-2016, Build:6.16.10.31, Ver:6.16.10.31

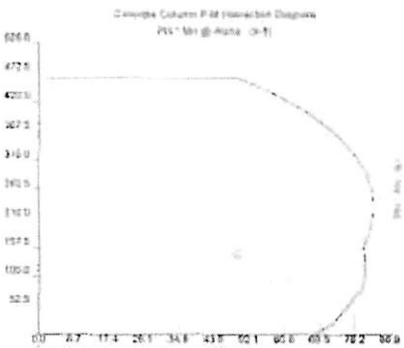
Lic. # : KW-06002489 — Licensee : ARW ENGINEERS

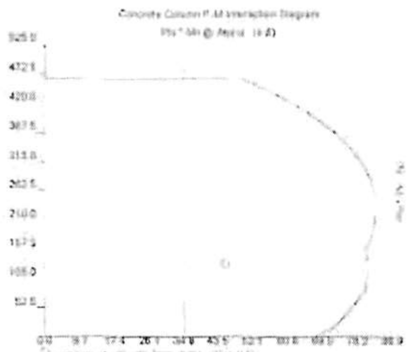
Description : 14" Square Concrete Column

Sketches



Interaction Diagrams





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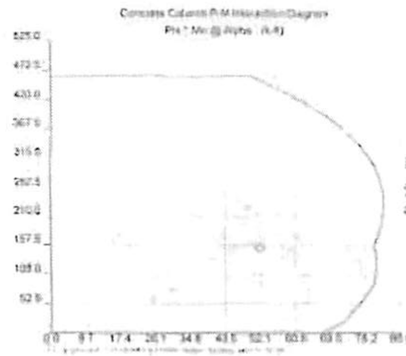

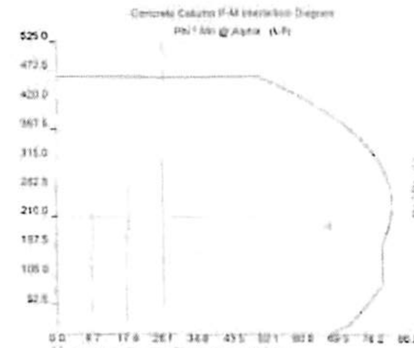

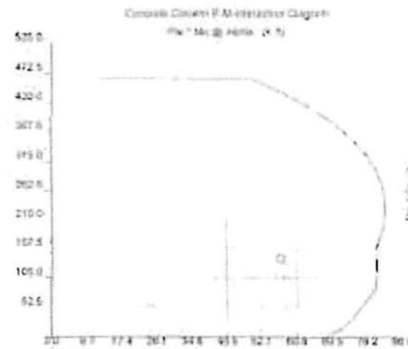

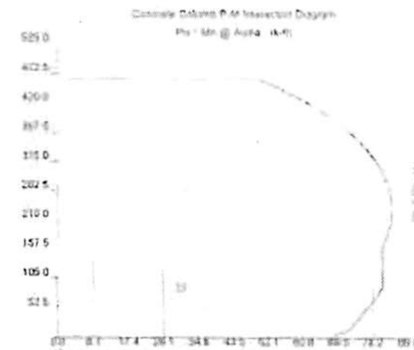

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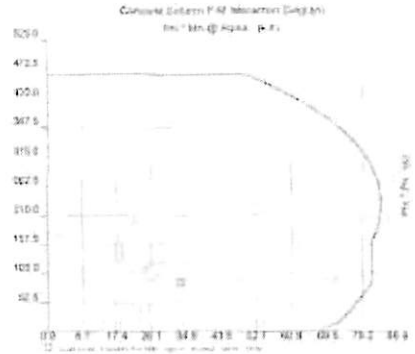
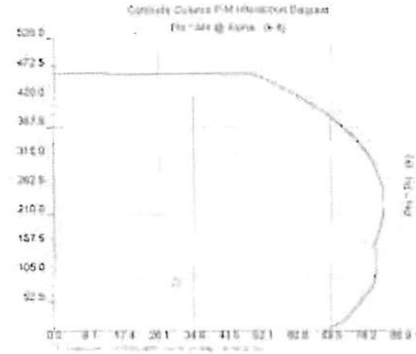
Concrete Column

Description: 14" Square Concrete Column





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Concrete Column

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ENERCALC, INC. 1983-2016, Build 6.16.10.31, Ver 6.16.10.31

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Description : 16" Concrete Column

Code References

Calculations per ACI 318-11, IBC 2012, CBC 2013, ASCE 7-10
Load Combinations Used : ASCE 7-10

General Information

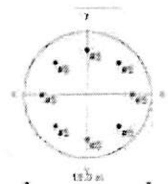
f'c : Concrete 28 day strength	=	4.50 ksi
E =	=	3,823.68 ksi
Density	=	150.0 pcf
β	=	0.8250
fy - Main Rebar	=	60.0 ksi
E - Main Rebar	=	29,000.0 ksi
Allow. Reinforcing Limits		ASTM A615 Bars Used
Min. Reinf.	=	1.0 %
Max. Reinf.	=	8.0 %

Overall Column Height = 17.0 ft
End Fixity : Top & Bottom Pinned
Brace condition for deflection (buckling) along columns :
X-X (width) axis :
Unbraced Length for X-X Axis buckling = 17.0 ft, K = 1.0
Y-Y (depth) axis :
Unbraced Length for X-X Axis buckling = 17.0 ft, K = 1.0

Column Cross Section

Column Dimensions : 16.0in Diameter, Column Edge to Rebar Edge Cover = 2.0in

Column Reinforcing : 8.0 - #5 bars



Applied Loads

Entered loads are factored per load combinations specified by user

Column self weight included : 3,560.47 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 17.0 ft above base, Xecc = 3.0in, Yecc = 3.0in, D = 60.20, S = 38.0, H = 35.0 k
BENDING LOADS . . .
Lat. Uniform Load creating Mx-x, E = 0.1490 k/ft

DESIGN SUMMARY

Load Combination	+1.20D+1.60S+1.60H
Location of max.above base	16.866 ft
Maximum Stress Ratio	**0.648 : 1**

Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	193.313 k	φ * Pn =	297.576 k
Mu-x =	-47.260 k-ft	φ * Mn-x =	-72.903 k-ft
Mu-y =	47.260 k-ft	φ * Mn-y =	72.903 k-ft
Mu Angle =	45.0 deg		
Mu at Angle =	66.836 k-ft	φMn at Angle =	103.150 k-ft

Pn & Mn values located at Pu-Mu vector intersection with capacity curve

Column Capacities . . .

Pnmax : Nominal Max. Compressive Axial Capacity	908.38 k
Pnmin : Nominal Min. Tension Axial Capacity	-148.80 k
φ Pn, max : Usable Compressive Axial Capacity	579.09 k
φ Pn, min : Usable Tension Axial Capacity	-111.60 k

Maximum SERVICE Load Reactions . .

Top along Y-Y	1.959 k	Bottom along Y-Y	1.959 k
Top along X-X	2.484 k	Bottom along X-X	1.959 k

Maximum SERVICE Load Deflections . . .

Along Y-Y -0.08748 in at 9.926 ft above base
for load combination : +D+S+H
Along X-X 0.08748 in at 9.926 ft above base
for load combination : +D+S+H

General Section Information . φ = 0.750 β = 0.8250 θ = 0.850

ρ : % Reinforcing 1.233 % Rebar % Ok
Reinforcing Area 2.480 in^2
Concrete Area 201.062 in^2

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	δ x	δ x * Mux	δ Y	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.40D+1.60H	Actual	Actual	16.87	111.25	402.61	1.000	25.47	1.000	25.57	45.000	36.10	101.02	0.483

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ENERCALC, INC. 1983-2016, Build 6.16.10.31, Ver 6.16.10.31

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Description : 16" Concrete Column

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	δ x	δ x * Mux	δ Y	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.20D+1.60H	Actual	Actual	16.89	132.51	303.81	1.000	-32.06	1.000	32.10	45.000	45.34	101.10	0.440
+1.20D+0.50S+1.60H	Actual	Actual	15.89	151.51	300.91	1.000	-36.81	1.000	36.91	45.000	[illegible]	103.60	0.503
+1.20D+1.60S+1.60H	Actual	Actual	15.88	150.31	297.58	1.000	-47.26	1.000	47.26	45.000	66.84	103.15	0.648
+1.20D+0.20S+E+1.60H	Actual	Actual	16.89	140.11	293.48	1.344	-45.65	1.000	[illegible]	45.000	[illegible]	104.11	0.347
+0.90D+0.90H	Actual	Actual	16.89	98.58	304.83	1.000	21.87	1.000	21.12	45.000	31.25	103.02	0.294
+0.90D+E+0.90H	Actual	Actual	16.87	88.98	275.27	1.164	25.58	1.000	21.49	45.000	17.38	103.42	0.331

Maximum Reactions

Note : Only non-zero reactions are listed

Load Combination	Reaction along X-X Axis @ Base	Reaction along X-X Axis @ Top	Reaction along Y-Y Axis @ Base	Reaction along Y-Y Axis @ Top	Axial Reaction @ Base
+D+H	1.400	1.400 k	1.400	1.400 k	98.760 k
+D+S+H	1.959	1.959 k	1.959	1.959 k	136.760 k
+D+0.750S+H	1.819	1.818 k	1.819	1.819 k	127.260 k
+D+0.70E+H	1.400	1.400 k	0.513	2.287 k	98.760 k
+D+0.750S+0.5250E+H	1.819	1.819 k	1.154	2.484 k	127.260 k
+0.60D+0.60H	0.840	0.840 k	0.840	0.840 k	59.256 k
+0.60D+0.70E+0.60H	0.840	0.840 k	0.047	1.727 k	59.256 k
D Only	0.885	0.885 k	0.885	0.885 k	63.760 k
S Only	0.559	0.559 k	0.559	0.559 k	38.000 k
E Only		k	1.267	1.267 k	k
H Only	0.515	0.515 k	0.515	0.515 k	35.000 k

Maximum Moments

Note : Only non-zero reactions are listed

Load Combination	Moment About X-X Axis @ Base	Moment About X-X Axis @ Top		Moment About Y-Y Axis @ Base	Moment About Y-Y Axis @ Top	
+D+H	23.800		k-ft	23.800		k-ft
+D+S+H	33.300		k-ft	33.300		k-ft
+D+0.750S+H	30.925		k-ft	30.925		k-ft
+D+0.70E+H	23.800		k-ft	23.800		k-ft
+D+0.750S+0.5250E+H	30.925		k-ft	30.925		k-ft
+0.60D+0.60H	14.280		k-ft	14.280		k-ft
+0.60D+0.70E+0.60H	14.280		k-ft	14.280		k-ft
D Only	15.050		k-ft	15.050		k-ft
S Only	9.500		k-ft	9.500		k-ft
E Only			k-ft			k-ft
H Only	8.750		k-ft	8.750		k-ft

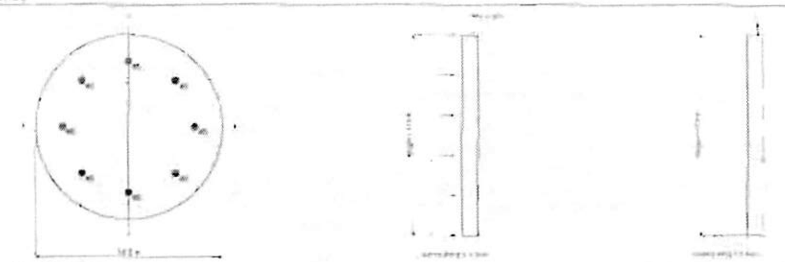
Maximum Deflections for Load Combinations

Load Combination	Max. X-X Deflection		Distance		Max. Y-Y Deflection		Distance	
+D+H	0.0625	in	9.926	ft	-0.063	in	9.926	ft
+D+S+H	0.0875	in	9.926	ft	-0.087	in	9.926	ft
+D+0.750S+H	0.0812	in	9.926	ft	-0.081	in	9.926	ft
+D+0.70E+H	0.0625	in	9.926	ft	-0.047	in	10.383	ft
+D+0.750S+0.5250E+H	0.0812	in	9.926	ft	-0.070	in	10.154	ft
+0.60D+0.60H	0.0375	in	9.926	ft	-0.038	in	9.926	ft
+0.60D+0.70E+0.60H	0.0375	in	9.926	ft	-0.022	in	10.839	ft
D Only	0.0395	in	9.926	ft	-0.040	in	9.926	ft
S Only	0.0250	in	9.926	ft	-0.025	in	9.926	ft
E Only	0.0000	in	0.000	ft	0.023	in	8.557	ft
H Only	0.0230	in	9.926	ft	-0.023	in	9.926	ft

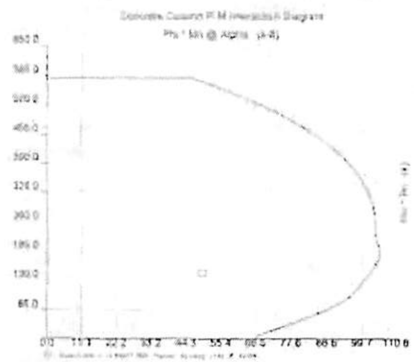
Concrete Column

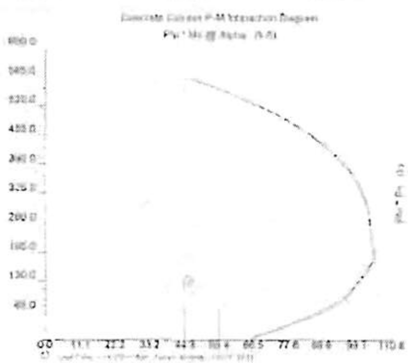
Description : 16" Concrete Column

Sketches



Interaction Diagrams





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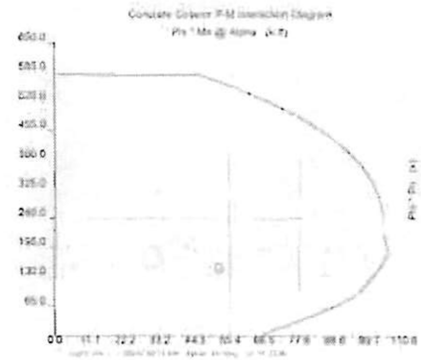
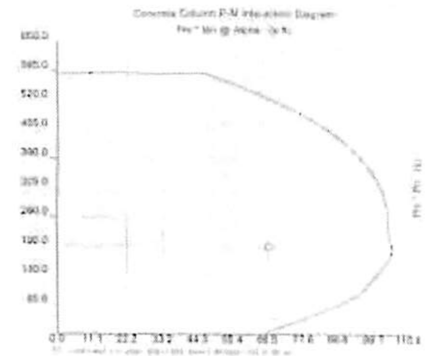
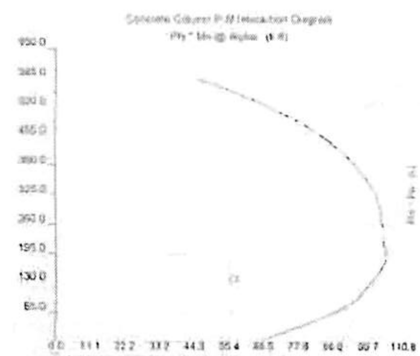
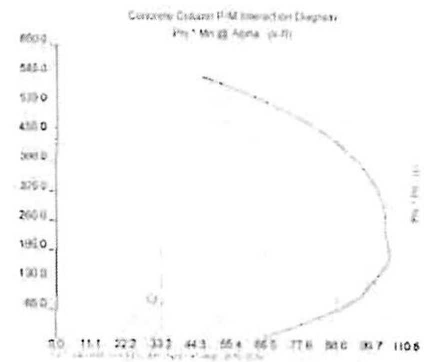








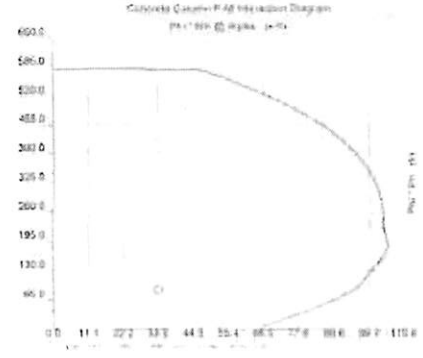
Title Block Line 1
You can changes this area
using the "Settings" menu item
and then using the "Printing &
Title Block" selection
Title Block Line 6

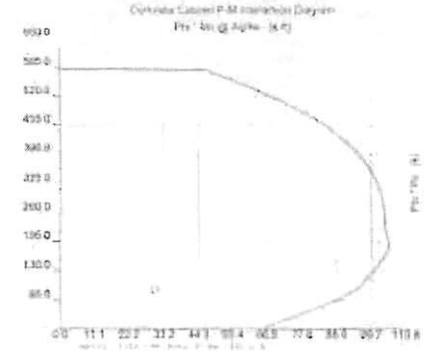
Project Title
Engineer:
Project Desc:

Project ID:

Concrete Column

Description : 18" Concrete Column





Title Block Line 1
You can changes this area using the "Settings" menu item and then using the "Printing & Title Block" selection.
Title Block Line 6

Project Title:
Engineer:
Project Descr:

Project ID

General Footing

Description: Typical Column Footing

Code References

Calculations per ACI 318-11, IBC 2012, CBC 2013, ASCE 7-10
Load Combinations Used: ASCE 7-10

General Information

Material Properties			Soil Design Values		
f'c : Concrete 28 day strength	=	4.50 ksi	Allowable Soil Bearing	=	3.50 ksf
fy : Rebar Yield	=	60.0 ksi	Increase Bearing By Footing Weight	=	No
Ec : Concrete Elastic Modulus	=	3,823.68 ksi	Soil Passive Resistance (for Sliding)	=	250.0 pcf
Concrete Density	=	145.0 pcf	Soil/Concrete Friction Coeff.	=	0.30
φ Values Flexure	=	0.90			
Shear	=	0.750			

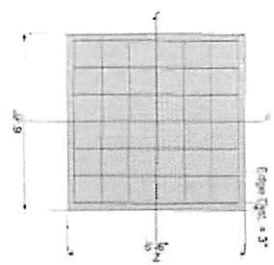
Analysis Settings			Increases based on footing Depth		
Min Steel % Bending Reinf.	=		Footing base depth below soil surface	=	0.0 ft
Min Allow % Temp Reinf.	=	0.00180	Allow press. increase per foot of depth when footing base is below	=	0.0 ksf
Min. Overturning Safety Factor	=	1.0 : 1		=	0.0 ft
Min. Sliding Safety Factor	=	1.0 : 1	**Increases based on footing plan dimension**		
Add Ftg Wt for Soil Pressure		Yes	Allowable pressure increase per foot of depth		
Use ftg wt for stability, moments & shears		Yes		=	0.0 ksf
Add Pedestal Wt for Soil Pressure		No	when max. length or width is greater than	=	0.0 ft
Use Pedestal wt for stability, mom & shear		No			

Dimensions

Width parallel to X-X Axis	=	6.50 ft
Length parallel to Z-Z Axis	=	6.50 ft
Footing Thickness	=	18.0 in

Pedestal dimensions...

px : parallel to X-X Axis	=	14.0 in
pz : parallel to Z-Z Axis	=	14.0 in
Height	=	0.0 in
Rebar Centerline to Edge of Concrete at Bottom of footing	=	3.0 in



Reinforcing

Bars parallel to X-X Axis			
Number of Bars	=		7
Reinforcing Bar Size	=	#	6
Bars parallel to Z-Z Axis			
Number of Bars	=		7
Reinforcing Bar Size	=	#	6

Bandwidth Distribution Check (ACI 15.4.4.2)

Direction Requiring Closer Separation	n/a
# Bars required within zone	n/a
# Bars required on each side of zone	n/a

Applied Loads

		D	Lr	L	S	W	E	H
P : Column Load	=	60.20	0.0	0.0	38.0	0.0	0.0	35.0 k
OB : Overburden	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0 ksf
M-xx	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0 k-ft
M-zz	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0 k-ft
V-x	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0 k
V-z	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0 k

Title Block Line 1
You can changes this area using the "Settings" menu item and then using the "Printing & Title Block" selection.
Title Block Line 6

Project Title:
Engineer:
Project Descr:

Project ID

General Footing

Projects 2016\16402 - Water Tank at Wolf Creek\Engineering\Calculations\Other\16402 wolf creek water tank.ec6
ENERCALC, INC. 1983-2016, Build 6.16.10.31, Ver: 6.16.10.31
Lic. # : KW-06002433 Licensee : ARW ENGINEERS

Description: Typical Column Footing

DESIGN SUMMARY

Design OK

	Min. Ratio	Item	Applied	Capacity	Governing Load Combination
PASS	0.9560	Soil Bearing	3.346 ksf	3.50 ksf	+D+S+H about Z-Z axis
PASS	n/a	Overturning - X-X	0.0 k-ft	0.0 k-ft	No Overturning
PASS	n/a	Overturning - Z-Z	0.0 k-ft	0.0 k-ft	No Overturning
PASS	n/a	Sliding - X-X	0.0 k	0.0 k	No Sliding
PASS	n/a	Sliding - Z-Z	0.0 k	0.0 k	No Sliding
PASS	n/a	Uplift	0.0 k	0.0 k	No Uplift
PASS	0.5878	Z Flexure (+X)	15.905 k-ft	27.060 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.5878	Z Flexure (-X)	15.905 k-ft	27.060 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.5878	X Flexure (+Z)	15.905 k-ft	27.060 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.5878	X Flexure (-Z)	15.905 k-ft	27.060 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.4632	1-way Shear (+X)	46.608 psi	100.623 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4632	1-way Shear (-X)	46.608 psi	100.623 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4632	1-way Shear (+Z)	46.608 psi	100.623 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4632	1-way Shear (-Z)	46.608 psi	100.623 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.5947	2-way Punching	119.683 psi	201.246 psi	+1.20D+0.50L+1.60S+1.60H

Detailed Results

Soil Bearing

Rotation Axis & Load Combination...	Gross Allowable	Xecc (in)	Zecc (in)	Actual Soil Bearing Stress @ Location Bottom, -Z	Top, +Z	Left, -X	Right, +X	Actual / Allow Ratio
X-X, +D+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+L+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+Lr+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+S+H	3.50	n/a	0.0	3.346	3.346	n/a	n/a	0.956
X-X, +D+0.750Lr+0.750L+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+0.750L+0.750S+H	3.50	n/a	0.0	3.121	3.121	n/a	n/a	0.892
X-X, +D+0.60W+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+0.70E+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+0.750Lr+0.750L+0.450W+H	3.50	n/a	0.0	2.447	2.447	n/a	n/a	0.699
X-X, +D+0.750L+0.750S+0.450W+H	3.50	n/a	0.0	3.121	3.121	n/a	n/a	0.892
X-X, +D+0.750L+0.750S+0.5250E+H	3.50	n/a	0.0	3.121	3.121	n/a	n/a	0.892
X-X, +0.60D+0.60W+0.60H	3.50	n/a	0.0	1.468	1.468	n/a	n/a	0.419
X-X, +0.60D+0.70E+0.60H	3.50	n/a	0.0	1.468	1.468	n/a	n/a	0.419
Z-Z, +D+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+L+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+Lr+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+S+H	3.50	0.0	n/a	n/a	n/a	3.346	3.346	0.956
Z-Z, +D+0.750Lr+0.750L+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+0.750L+0.750S+H	3.50	0.0	n/a	n/a	n/a	3.121	3.121	0.892
Z-Z, +D+0.60W+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+0.70E+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+0.750Lr+0.750L+0.450W+H	3.50	0.0	n/a	n/a	n/a	2.447	2.447	0.699
Z-Z, +D+0.750L+0.750S+0.450W+H	3.50	0.0	n/a	n/a	n/a	3.121	3.121	0.892
Z-Z, +D+0.750L+0.750S+0.5250E+H	3.50	0.0	n/a	n/a	n/a	3.121	3.121	0.892
Z-Z, +0.60D+0.60W+0.60H	3.50	0.0	n/a	n/a	n/a	1.468	1.468	0.419
Z-Z, +0.60D+0.70E+0.60H	3.50	0.0	n/a	n/a	n/a	1.468	1.468	0.419

Overturning Stability

Rotation Axis & Load Combination...	Overturning Moment	Resisting Moment	Stability Ratio	Status
Footing Has NO Overturning				

Sliding Stability

All units k

Force Application Axis Load Combination...	Sliding Force	Resisting Force	Stability Ratio	Status
Footing Has NO Sliding				

Title Block Line 1
You can changes this area using the "Settings" menu item and then using the "Printing & Title Block" selection.
Title Block Line 5

Project Title:
Engineer:
Project Descr:

Project ID:

General Footing

Description: Typical Column Footing

Footing Flexure

Flexure Axis & Load Combination	Mu k-ft	Side	Tension Surface	As Req'd in^2	Gvrn. As in^2	Actual As in^2	Phi*Mn k-ft	Status
X-X, +1.40D+1.60H	11.802	+Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK

Title Block Line 1
You can changes this area using the "Settings" menu item and then using the "Printing & Title Block" selection.
Title Block Line 5

Project Title:
Engineer:
Project Descr:

Project ID:

General Footing

[Projects 2016\16402 - Water Tank at Wolf Creek\Engineering Calculations\Other\16402 wolf creek water tank.ec]
ENERCALC, INC. 1983-2016, Build:6.16.10.31, Ver:6.16.10.31
Lic. # : KW-06002463 Licensee : ARW ENGINEERING

Description: Typical Column Footing

Footing Flexure

Flexure Axis & Load Combination	Mu k-ft	Side	Tension Surface	As Req'd in^2	Gvrn. As in^2	Actual As in^2	Phi*Mn k-ft	Status
X-X, +1.40D+1.60H	11.802	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50Lr+1.60L+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50Lr+1.60L+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60L+0.50S+1.60H	12.388	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60L+0.50S+1.60H	12.388	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60L+0.50L+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60Lr+0.50L+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60L+0.50W+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+1.60Lr+0.50W+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50L+1.60S+1.60H	15.905	-Z	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
X-X, +1.20D+0.50L+1.60S+1.60H	15.905	-Z	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
X-X, +1.20D+1.60S+0.50W+1.60H	15.905	-Z	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
X-X, +1.20D+1.60S+0.50W+1.60H	15.905	-Z	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
X-X, +1.20D+0.50Lr+0.50L+W+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50Lr+0.50L+W+1.60H	10.789	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50L+0.50S+W+1.60H	12.388	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50L+0.50S+W+1.60H	12.388	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50L+0.20S+E+1.60H	11.429	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +1.20D+0.50L+0.20S+E+1.60H	11.429	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +0.90D+W+0.90H	7.209	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +0.90D+W+0.90H	7.209	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +0.90D+E+0.90H	7.209	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
X-X, +0.90D+E+0.90H	7.209	-Z	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.40D+1.60H	11.802	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.40D+1.60H	11.802	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50Lr+1.60L+1.60H	10.789	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50Lr+1.60L+1.60H	10.789	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50S+1.60H	12.388	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50S+1.60H	12.388	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50L+1.60H	10.789	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50L+1.60H	10.789	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50W+1.60H	10.789	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+1.60L+0.50W+1.60H	10.789	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+1.60S+1.60H	15.905	-X	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+1.60S+1.60H	15.905	+X	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
Z-Z, +1.20D+1.60S+0.50W+1.60H	15.905	-X	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
Z-Z, +1.20D+1.60S+0.50W+1.60H	15.905	+X	Bottom	0.3675980767574	Min ACI 10.5	0.4738	27.060	OK
Z-Z, +1.20D+0.50Lr+0.50L+W+1.60H	10.789	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50Lr+0.50L+W+1.60H	10.789	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+0.50S+W+1.60H	12.388	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+0.50S+W+1.60H	12.388	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+0.20S+E+1.60H	11.429	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +1.20D+0.50L+0.20S+E+1.60H	11.429	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +0.90D+W+0.90H	7.209	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +0.90D+W+0.90H	7.209	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +0.90D+E+0.90H	7.209	-X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK
Z-Z, +0.90D+E+0.90H	7.209	+X	Bottom	0.3456	Min Temp %	0.4738	27.060	OK

One Way Shear

Load Combination	Vu @ -X	Vu @ +X	Vu @ -Z	Vu @ +Z	Vu,Max	Phi Vn	Vu / Phi*Vn	Status
+1.40D+1.60H	34.586 psi	34.586 psi	34.586 psi	34.586 psi	34.586 psi	100.623 psi	0.3437	OK
+1.20D+0.50Lr+1.60L+1.60H	31.617 psi	31.617 psi	31.617 psi	31.617 psi	31.617 psi	100.623 psi	0.3142	OK
+1.20D+1.60L+0.50S+1.60H	36.302 psi	36.302 psi	36.302 psi	36.302 psi	36.302 psi	100.623 psi	0.3608	OK
+1.20D+1.60Lr+0.50L+1.60H	31.617 psi	31.617 psi	31.617 psi	31.617 psi	31.617 psi	100.623 psi	0.3142	OK
+1.20D+1.60Lr+0.50W+1.60H	31.617 psi	31.617 psi	31.617 psi	31.617 psi	31.617 psi	100.623 psi	0.3142	OK
+1.20D+0.50L+1.60S+1.60H	46.608 psi	46.608 psi	46.608 psi	46.608 psi	46.608 psi	100.623 psi	0.4632	OK
+1.20D+1.60S+0.50W+1.60H	46.608 psi	46.608 psi	46.608 psi	46.608 psi	46.608 psi	100.623 psi	0.4632	OK
+1.20D+0.50Lr+0.50L+W+1.60H	31.617 psi	31.617 psi	31.617 psi	31.617 psi	31.617 psi	100.623 psi	0.3142	OK
+1.20D+0.50L+0.50S+W+1.60H	36.302 psi	36.302 psi	36.302 psi	36.302 psi	36.302 psi	100.623 psi	0.3608	OK
+1.20D+0.50L+0.20S+E+1.60H	33.491 psi	33.491 psi	33.491 psi	33.491 psi	33.491 psi	100.623 psi	0.3328	OK
+0.90D+W+0.90H	21.124 psi	21.124 psi	21.124 psi	21.124 psi	21.124 psi	100.623 psi	0.2099	OK
+0.90D+E+0.90H	21.124 psi	21.124 psi	21.124 psi	21.124 psi	21.124 psi	100.623 psi	0.2099	OK

General Footing

Description : Typical Column Footing

Punching Shear All units k

Load Combination...	Vu	Phi*Vn	Vu / Phi*Vn	Status
+1.40D+1.60H	88.813	201.246	0.4413	OK
+1.20D+0.50Lr+1.60L+1.60H	81.19	201.246	0.4034	OK
+1.20D+1.60L+0.50S+1.60H	93.219	201.246	0.4632	OK
+1.20D+1.60Lr+0.50L+1.60H	81.19	201.246	0.4034	OK
+1.20D+1.60Lr+0.50W+1.60H	81.19	201.246	0.4034	OK
+1.20D+0.50L+1.60S+1.60H	119.683	201.246	0.5947	OK
+1.20D+1.60S+0.50W+1.60H	119.683	201.246	0.5947	OK
+1.20D+0.50Lr+0.50L+W+1.60H	81.19	201.246	0.4034	OK
+1.20D+0.50L+0.50S+W+1.60H	93.219	201.246	0.4632	OK
+1.20D+0.50L+0.20S+E+1.60H	86.002	201.246	0.4273	OK
+0.90D+W+0.90H	54.245	201.246	0.2695	OK
+0.90D+E+0.90H	54.245	201.246	0.2695	OK

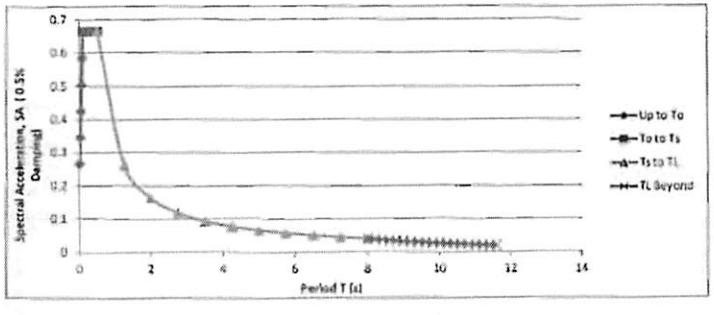
Project Name LPC - Upper System Tank
Project # 16194
Prepared By WWY
Date 11/21/2016

Program Authors: TAB & DOC
Last Revised: 1/19/2006
Reviewed By: TAB

ENGINEERS

D_{tank}	75	ft	
H_L	16	ft	
g	32.17	ft/s²	
A	6.80989322		
T_C	6.176463161	s	
S_{D1}	0.312	g	
S_{DS}	0.636	g	
T_S	0.490566038	s	
C_C	0.040011851		
I	1.25		
d_{max}	1.875555831	ft	Required Freeboard

Tank Volume	512241	Gallons	
Ht to Water	15.5	ft	
New H_L	15.5	ft	Height to Liquid after Freeboard Check (IF desired to change from above)
New d_f	0.5	ft	
H_s	17	ft	height above base to highest level of structure
T	0.167442881	s	Approximate Fundamental Period as Per ASCE 7 eqn 12.8-7
T_o	0.098113208	s	Per ASCE 7
T_s	0	s	Per ASCE 7 (fig 22-15)
S_a	0.444281016	g	For periods less than T_o
S_a	0.636	g	For periods >= to T_o and <= to T_s



Find Pressure at Roof to Shell Interface from Insufficient freeboard depth.

SA (T_C)	0.050514346	g	Spectral Acceleration at Tc
Theta	2.89180086	degrees	Angle of free surface at sloshing load
h_r	0.5	ft	height from top of wall to underside of topmost point of lid
V_{Empty}	2945.243113	ft³	Empty Volume of tank above water
d	1.894287992	ft	Vertical displacement of liquid surface
d/d	0.263951417		
h_r/d	0.263951417		
X_r/R	0.75		Fig 6 from "Earthquake Induced Sloshing in Tanks with Insufficient Freeboard"
X_r	28.125	ft	
ρ	1.94	slugs/ft³	mass density of liquid
P_{max}	26.16	psf	Weight of Roof is heavier, therefore ok
F_{max}	367.82	plf	#5 Radial Dowels @ 16" o.c. okay (Roof Slab to Wall)

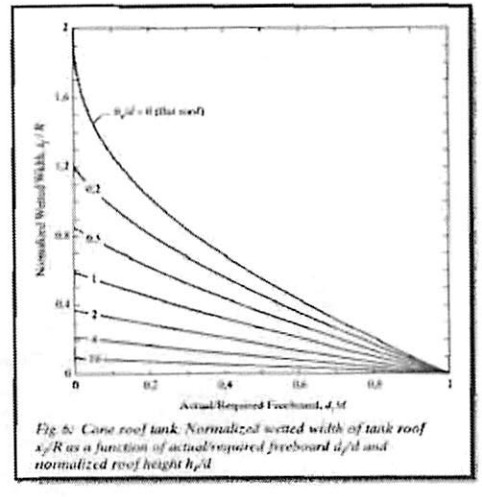


Fig 6: Cone roof tank: Normalized wetted width of tank roof x_r/R as a function of actual/required freeboard d_f/d and normalized roof height h_r/d

Weight

D/H_L	4.838709677			
Wi/W_L	0.25	PCA EB219 fig 4-4 (b)		
Wc/W_L	0.73	PCA EB219 fig 4-4 (b)		
W_L	4451 kips	Weight Of Water		
Wi	1113 kips	Impulsive Weight		
Wc	3249 kips	Convective Weight		
Tw	12 inches	Wall Thickness	$D_{o.to}$	77.00 ft
Tr	8 inches	Roof Thickness		
W_W	573 kips	Weight of Walls		
W_R	466 kips	Weight of Roof		

Period

Cw	0.13	PCA EB219 fig 4-10
C_L	0.21	
Ec	3823 ksi	Elastic Modulus of Concrete
ρ_c	4.66 # s/ft^4	Mass Density of Concrete
ω_i	148.8628937 rad/s	
T_i	0.04 s	

Base Shear

R	1.5	Response Modification Factor
C_{is}	0.53	
$C_{i\,(0.5)}$	0.16	
C_{is}	0.53	
$C_{ac\,(TC)}$	0.04	
Vi	1425 kips	Impulsive Base Shear
Vc	171 kips	Convective Base Shear
V_T	1436 kips	Total Base Shear

Overturning Moment

h_i/H_L	0.375	PCA EB219	fig 4-5 (b)
h_c/H_L	0.53	PCA EB219	fig 4-5 (b)
h_i	5.8125 ft		
h_c	8.215 ft		
h_w	8 ft		
M_i	9806 kip ft	Impulsive	
M_c	14147 kip ft	Convective (Per ACI 350)	
M_T	17213 kip ft	Total	

Overall Stability Check

Sliding (Neglecting Backfill)

Weight of tank w/out contents:

Walls	573 kips
Roof	466 kips
Columns	30 kips
Base Slab	454 kips
Water	4451 kips
Total Weight	5973 kips
Friction Coeff	0.35
Base Shear	1436
Safety Factor	1.46 ok

Overturning

OTM	17213 kip ft
RM	224006 kip ft
Safety Factor	13.0 ok

Design of Walls for In-Plane Loading

V_u	1436 kips	Base Shear	
R2	38.5 ft	Outside tank radius	
R1	37.5 ft	Inside tank radius	
Vc	12.0 kips/ft	Shear in wall	
α_c	3	See ACI 318 eqn 21-7	
ρ_t	0.008333	See ACI 318 eqn 21-7	#6 at 12" oc EF
φV_n	74.5 kips/ft	ok	

PER PCA EB219 for D>>H out of plane bending effects are small and can be neglected

FOOTINGS

COLUMN FTG

DL = 60.2K
S = 38K
H = 35K

USE 6.5x6.5 FTG w/ (7) #6 BARS

WALL FOOTINGS

DL = 115 psf (18.75')(½) = 1.1 KLF + WALL DL = $\frac{12"}{12}$(150 pcf)(16') = 2,400 PLF
S = 82 psf (18.75')(½) = 769 PLF
H = 75 psf (18.75')(½) = 703 PLF

USE 3'-0" x 16" FTG w/ (3) #6 BARS