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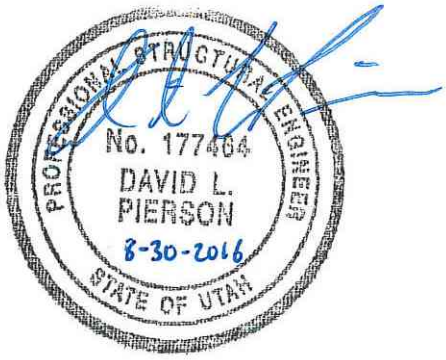
Structural Calculations

For

LPC – Upper System Tank

Project Number: 16194

August 31, 2016



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

Design Criteria

Snow Load: 100 psf (see spreadsheet)

Max Soil over Cover: 6" (75 psf)

Soil Bearing Pressure: 4000 psf

At Rest Horiz. Pressure: 57 pcf

Seismic Active Pressure: 46 pcf

Tank Geometry

Inside Diameter = 53'-0"

(4) interior columns spaced @ 17'-8" o.c.

Wall height = 16'-0"

Overflow @ 15'-6"

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UTAH SNOW LOAD STUDY

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

Project: Liberty Upper System Tank

Description:

Date: 8/17/2016

Job#: 16194

By: DLP

County: Weber

Po:	43	psf
S:	63	psf/1000 ft.
A_o:	4.5	ft./1000
A:	5975	ft.

Pg: 102.4 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

Environmental Durability Factor

ACI 350-06 Section 9.2.6

$S_d = \frac{\phi f_y}{\gamma f_s} \geq 1.0$ where $\gamma = \frac{\text{factored load}}{\text{unfactored load}}$

$f_s = 20$ KSI (section 9.2.6.2)

* This applies to direct & hoop tensile stress.

Water $S_d = \frac{0.9 \cdot 60\,KSI}{1.4 \cdot 20\,KSI} = 1.93$

Soil $S_d = \frac{0.9 \cdot 60\,KSI}{1.6 \cdot 20\,KSI} = 1.69$

* Soil creates compression forces in hoop ∴ use $S_d = 1.0$

Flexural Stress

$f_s = \frac{320}{\beta \sqrt{s^2 + 4(2 + d_b/2)^2}}$ [ACI 350-06 Eq. 10-4]

$f_s = 20$ KSI (conservative)

$S_d = \frac{0.90 \cdot 60\,KSI}{1.4 \cdot 20\,KSI} = 1.93$

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Reviewed By: TAB

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Circular Concrete Tanks without Prestressing

(Based on the 1993 PCA Document)

Design Criteria

f'c	4500	psi
D_{tank}	53	ft
H_{tank}	16	ft
t_{wall}	12	in
Fluid Pressure	62.4	pcf
Soil Pressure	57	pcf
E_s	29000000	psi
E_c	3823676.24	psi
n	7.6	
Surcharge	175	pcf
Soil on Lid	1	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	4.83	

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}	43647	lbs.
$T_{unfactored}$	16154	lbs.
$A_{s(req'd)}$	0.81	in^2
$A_{s(used)}$	0.88	in^2

OK #6 @ 12" o.c. Each Face

$F_{t(conc)}$ 158 psi

This equates to 3.51 % of f'c
Wall thickness is OK

Compression Check	
F'c	423
0.33f'c	1485
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= 71488.4352

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	-268	0	0
0.1H	0.118	8429	0.0000	12
0.2H	0.238	17018	0.0002	139
0.3H	0.358	25583	0.0008	532
0.4H	0.469	33528	0.0019	1304
0.5H	0.559	39970	0.0038	2618
0.6H	0.611	43647	0.0061	4241
0.7H	0.597	42679	0.0085	5865
0.8H	0.493	35279	0.0098	6773
0.9H	0.288	20556	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= 1 ft
p 175

Ring Force=(A-5 Coef.)w_uHR+(A-6 Coef.)pR
w_uHR= -74631
pR= -14320.6

Moment=(A-7 Coef.)($w_u h^3+ph^2$)
$w_u h^3+ph^2$= -752447

	A-5 Coef	RF (#)	A-6 Coef.	RF (#)	Total RF (#)	A-7 Coef.	Moment (#-ft/ft)
Top	-0.004	280	0.996	-14266.8302	-13987	0	0
0.1H	0.118	-8799	1.018	-14577.0198	-23376	0.0000	-13
0.2H	0.238	-17766	1.038	-14865.5934	-32632	0.0002	-152
0.3H	0.358	-26708	1.058	-15149.3034	-41857	0.0008	-579
0.4H	0.469	-35002	1.069	-15308.7214	-50311	0.0019	-1421
0.5H	0.559	-41727	1.059	-15167.1366	-56894	0.0038	-2852
0.6H	0.611	-45566	1.011	-14471.6418	-60037	0.0061	-4621
0.7H	0.597	-44555	0.897	-12845.5782	-57400	0.0085	-6390
0.8H	0.493	-36830	0.693	-9931.201	-46761	0.0098	-7380
0.9H	0.288	-21460	0.388	-5549.908	-27010	0.0080	-6048
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) = -13987 #

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= -1046 #
VR/H= -1733 #

$Delta_{RF}$=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_{DM}/S_{DC})

$Delta_{mom}$=(A-9 Coef.)VH
VH= -16742

	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	13987	-13987	0	0	0	0	0
0.1H	-4.946	8571	-23376	-14805	0.0647	-1083	-13	-1096
0.2H	-2.475	4290	-32632	-28342	0.0797	-1334	-152	-1486
0.3H	-0.843	1460	-41857	-40397	0.0694	-1162	-579	-1741
0.4H	0.059	-102	-50311	-50413	0.0497	-832	-1421	-2253
0.5H	0.434	-753	-56894	-57647	0.0305	-511	-2852	-3364
0.6H	0.480	-831	-60037	-60868	0.0150	-252	-4621	-4873
0.7H	0.363	-629	-57400	-58030	0.0042	-70	-6390	-6460
0.8H	0.198	-344	-46761	-47104	-0.0027	45	-7380	-7335
0.9H	0.060	-104	-27010	-27114	-0.0075	126	-6048	-5922
Bottom	0.000	0	0	0	-0.0124	207	0	207

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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= -33 # (For Ring Force)
VH= -321 # (For Moment)

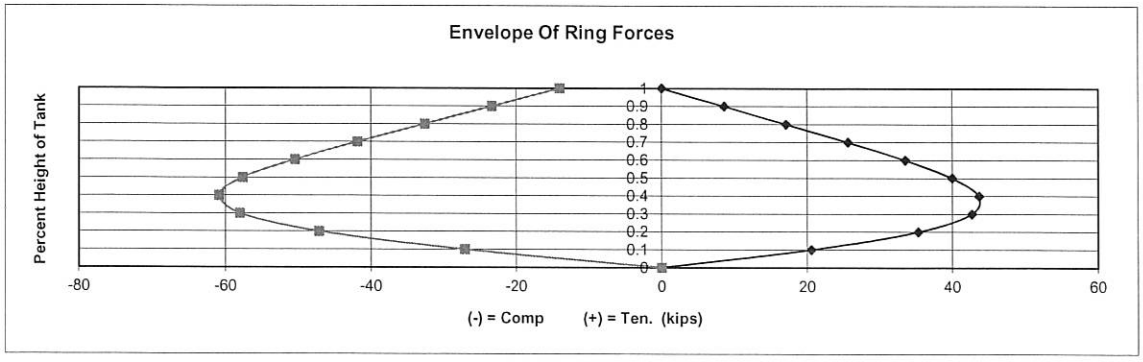
	A-8 Coef.	$Delta_{RF}$ (#)	LC#1 RF (#)	Total RF (#)	A-9 Coef.	$Delta_{mom}$ (#-ft/ft)	LC#1 Moment (#-ft/ft)	Total Moment (#-ft/ft)
Top	-8.07	268	-268	0	0	0	0	0
0.1H	-4.95	164	8429	8593	0.065	-21	12	-9
0.2H	-2.48	82	17018	17101	0.080	-26	139	114
0.3H	-0.84	28	25583	25611	0.069	-22	532	509
0.4H	0.06	-2	33528	33526	0.050	-16	1304	1288
0.5H	0.43	-14	39970	39956	0.031	-10	2618	2608
0.6H	0.48	-16	43647	43631	0.015	-5	4241	4237
0.7H	0.36	-12	42679	42667	0.004	-1	5865	5864
0.8H	0.20	-7	35279	35272	-0.003	1	6773	6774
0.9H	0.06	-2	20556	20554	-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	-268	-13987	0	0	0	-13987
0.1H	8429	-23376	-14805	8593	8593	-23376
0.2H	17018	-32632	-28342	17101	17101	-32632
0.3H	25583	-41857	-40397	25611	25611	-41857
0.4H	33528	-50311	-50413	33526	33528	-50413
0.5H	39970	-56894	-57647	39956	39970	-57647
0.6H	43647	-60037	-60868	43631	43647	-60868
0.7H	42679	-57400	-58030	42667	42679	-58030
0.8H	35279	-46761	-47104	35272	35279	-47104
0.9H	20556	-27010	-27114	20554	20556	-27114
Bottom	0	0	0	0	0	0

	Tension	Compression
Bottom	0	0
0.9H	21	-27
0.8H	35	-47
0.7H	43	-58
0.6H	44	-61
0.5H	40	-58
0.4H	34	-50
0.3H	26	-42
0.2H	17	-33
0.1H	9	-23
Top	0	-14

Controls



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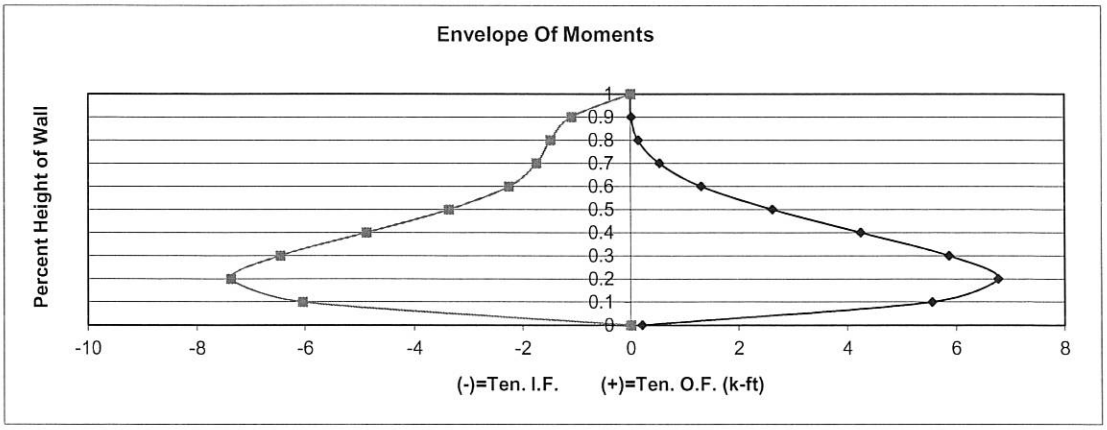
Envelope of Moments

	LC#1	LC#2	LC#3	LC#4	Max	Min
Top	0	0	0	0	0	0
0.1H	12	-13	-1096	-9	12	-1096
0.2H	139	-152	-1486	114	139	-1486
0.3H	532	-579	-1741	509	532	-1741
0.4H	1304	-1421	-2253	1288	1304	-2253
0.5H	2618	-2852	-3364	2608	2618	-3364
0.6H	4241	-4621	-4873	4237	4241	-4873
0.7H	5865	-6390	-6460	5864	5865	-6460
0.8H	6773	-7380	-7335	6774	6774	-7380
0.9H	5551	-6048	-5922	5553	5553	-6048
Bottom	0	0	207	4	207	0

	Tension O.F.	Tension I.F.
Bottom	0	0
0.9H	6	-6
0.8H	7	-7
0.7H	6	-6
0.6H	4	-5
0.5H	3	-3
0.4H	1	-2
0.3H	1	-2
0.2H	0	-1
0.1H	0	-1
Top	0	0

Controls



Design of Wall Steel

Ring Steel

- Compression

$f_c = C/A = 61^k / 12 \cdot 12 = 424$ psi

$C = 61^k$ @ $0.6H$

$1/3\,(4500\text{ psi}) = 1500\text{ psi} > 473\text{ psi}$ ∴ OK

- Tension

$A_s = 44.0^k / 0.9 \cdot 60\text{ KSI} = 0.82\ IN^2$

USE #6 BARS @ 12" o.c. Each Face = $0.88\ IN^2 > 0.82\ IN^2$ ∴ OK

Minimum shrinkage steel = $0.005\,(12")(12") = 0.72\ IN^2/ft$

USE #6 BARS @ 12" o.c. Each Face over full height of wall

F_t OK (see Spreadsheet)

Design of Wall Steel

Moment Reinforcing

- Steel at Interior Face

$M_u = 7$ K-ft

$$\frac{M_u}{\phi f'_c b d^2} = \frac{7\text{k-ft} \cdot 12}{0.9 \cdot 4.5 \cdot 12" \cdot 9.5^2} = 0.019151$$

$w = 0.0200$ [Table A-20]

$$\rho = 0.0200 \cdot {}^{4.5}/_{60} = 0.0015$$

ρ_{min} (temp. shrinkage) $= 0.003$

$A_{s,min} = 0.003 \cdot 12 \cdot 12 = 0.432\ in^2/ft$ (Each Face)

$$A_{s,min}\ (\text{flexure}) = \frac{3\sqrt{4500}}{60000} \cdot 12" \cdot 9.5" = 0.383\ in^2/ft$$

OR

$$A_{s,min}\ (\text{flexure}) = {}^{200 \cdot 12" \cdot 9.5"}/_{60,000} = 0.38\ in^2/ft$$

USE #6 BAR @ 12" o.c. E.F.

$0.44\ in^2/ft > 0.432\ in^2/ft$ ∴ OK

* This steel also works for exterior face

Shear Strength of Wall

$$\phi V_c = 0.75 \cdot 2 \cdot \sqrt{4500} \cdot 12" \cdot 9.5" = 11.4^k$$

$V_u = 0.236\ (1.6)(62.4\ pcf)(16^2) \cdot 1.69 = 10.2^k < 11.4^k$ ∴ OK

↑ coeff. PCA Table A-12

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CONCRETE LAP SPLICE TABLE

23-Aug-16
9:45 AM

JOB TITLE: LPC - Upper System Tank
BUILDING LOCATION : Liberty, UT

JOB #: 16194
PREPARED BY: WWY

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				

ENGINEERS

CONCRETE LAP SPLICE TABLE

26-Aug-16
10:07 AM

JOB TITLE: LPC - Upper System Tank - Horizontal Wall Reinforcement
BUILDING LOCATION : Liberty, UT

JOB #: 16194
PREPARED BY: WWY

Horizontal Wall Reinforcement

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	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
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	81		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				

ARW ENGINEERS
structural consultants

Project No. 16194 Sheet No.

Project LPC - Upper system Tank

Prepared By WWY Date 8/22/16

Tank Lid Design

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

Snow: 100 psf

↑ soil

* SEE SPREADSHEET

USE 8" SLAB w/ 4" drop panels that are 6'x6'

ENGINEERS
structural consultants

Concrete Water Tank - Roof Design

8/23/2016
9:46:06 AM

Version Date: 10/28/10 Author TAB
Job Title LPC - Upper System Tank Job # 16194

Roof Slab Design

Min Thickness

Slab Span	17.667	ft	Est. Column Thickness	16	in
h_{min}	5.94	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	100	psf
W_U	388	psf

Shear Capacity of Slab

Round Column Dim	16	in	
b_o	67.5442	in	
V_U	121.104	kips	
φV_C (No Drop Panel)	74.7616	kips	NG Use Drop Panel
Drop Panel Dimension	6	ft square	
New b_o	310	in	
φV_C Drop Panel	343.125	kips	Ok
Drop Panel Thickness	4	in	
b_o	80.1106	in	
φV_C	153.159	kips	Ok

min thickness = $\ell_n/33$ = 6.43" ∴ 8" slab is OK [ACI 350 9.5.3.2]

Flexural Design by Direct Design Method Of ACI 318

l_2	17.667	ft	S_d	1.93	
l_n	16.3337	ft	Strip Width	8.833	ft
M_O	228.598	K-ft			
Exterior Span M^+ factor	0.63		Exterior M^+ factored Moment	144.02	k-ft
Exterior Span M^- factor	0.75		Exterior M^- factored Moment	171.45	k-ft
Interior Span M^+ factor	0.35		Interior M^+ factored Moment	80.009	k-ft
Interior Span M^- factor	0.65		Interior M^- factored Moment	148.59	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	166.771	k-ft	Middle Strip	111.18	k-ft
Moment per foot of width	18.8805	k-ft/ft	Moment per foot of width	12.587	k-ft/ft
Mu/φ	20.9783	k-ft/ft	Mu/φ	13.986	k-ft/ft
Mu/φ	251.74	k-in/ft	Mu/φ	167.83	k-in/ft
As	0.84838	in^2	As	0.5437	in^2
a	1.10899		a	0.7107	
#4 Bar Spacing	2.83	in oc	#4 Bar Spacing	4.41	in oc
#5 Bar Spacing	4.38	in oc	#5 Bar Spacing	6.84	in oc
#6 Bar Spacing	6.22	in oc	#6 Bar Spacing	9.71	in oc
#7 Bar Spacing	8.49	in oc	#7 Bar Spacing	13.24	in oc
#8 Bar Spacing	11.17	in oc	#8 Bar Spacing	17.44	in oc

Exterior Negative Moment

Enter new d for Col strip	9.5				
Column Strip	248.171	k-ft	Middle Strip	82.724	k-ft
Moment per foot of width	28.0959	k-ft/ft	Moment per foot of width	9.3653	k-ft/ft
Mu/φ	31.2177	k-ft/ft	Mu/φ	10.406	k-ft/ft
Mu/φ	374.613	k-in/ft	Mu/φ	124.87	k-in/ft
As	0.68997	in^2	As	0.3971	in^2
a	0.90192		a	0.5191	
#4 Bar Spacing	3.48	in oc	#4 Bar Spacing	6.04	in oc
#5 Bar Spacing	5.39	in oc	#5 Bar Spacing	9.37	in oc
#6 Bar Spacing	7.65	in oc	#6 Bar Spacing	13.30	in oc
#7 Bar Spacing	10.44	in oc	#7 Bar Spacing	18.13	in oc
#8 Bar Spacing	13.74	in oc	#8 Bar Spacing	23.87	in oc

Interior Positive Moment

Column Strip	92.6507	k-ft	Middle Strip	61.767	k-ft
Moment per foot of width	10.4892	k-ft/ft	Moment per foot of width	6.9928	k-ft/ft
Mu/φ	11.6546	k-ft/ft	Mu/φ	7.7697	k-ft/ft
Mu/φ	139.855	k-in/ft	Mu/φ	93.237	k-in/ft
As	0.44761	in^2	As	0.2927	in^2
a	0.58512		a	0.3826	
#4 Bar Spacing	5.36	in oc	#4 Bar Spacing	8.20	in oc
#5 Bar Spacing	8.31	in oc	#5 Bar Spacing	12.71	in oc
#6 Bar Spacing	11.80	in oc	#6 Bar Spacing	18.04	in oc
#7 Bar Spacing	16.09	in oc	#7 Bar Spacing	24.60	in oc
#8 Bar Spacing	21.18	in oc	#8 Bar Spacing	32.39	in oc

Interior Negative Moment

Enter new d for Col strip	9.5	in			
Column Strip	215.082	k-ft	Middle Strip	71.694	k-ft
Moment per foot of width	24.3498	k-ft/ft	Moment per foot of width	8.1166	k-ft/ft
Mu/φ	27.0553	k-ft/ft	Mu/φ	9.0184	k-ft/ft
Mu/φ	324.664	k-in/ft	Mu/φ	108.22	k-in/ft
As	0.59385	in^2	As	0.3418	in^2
a	0.77627		a	0.4468	
#4 Bar Spacing	4.04	in oc	#4 Bar Spacing	7.02	in oc
#5 Bar Spacing	6.26	in oc	#5 Bar Spacing	10.88	in oc
#6 Bar Spacing	8.89	in oc	#6 Bar Spacing	15.45	in oc
#7 Bar Spacing	12.12	in oc	#7 Bar Spacing	21.06	in oc
#8 Bar Spacing	15.96	in oc	#8 Bar Spacing	27.73	in oc

How Far past support must negative moment reinf. Extend?

Column Strip	5.39011	ft	Use	6 ft
Middle Strip	3.59341	ft	Use	4 ft

Column Design

Loads on Column uses PCA Table A-13 coeff. = 1.320

Dead Load = 115 psf $(17'\text{-}8")^2 (1 + 0.2 \cdot 0.712)(1.320) = 54.2^k$

Snow Load = 100 psf $(17'\text{-}8")^2 (1.320) = 41.2^k$

Soil = 75 psf $(17'\text{-}8")^2 (1 + 0.2 \cdot .712)(1.320) = 35.3^k$

$E = \pi (1.0)(62.4\ ^{lbs}/_{ft^3}) (8"/12)^2 + 0.4 (0.712)(1.25)(\pi \cdot 150pcf \cdot (16"/12)^2/4) = 162$ plf

* SEE ENERCALC SOLUTION

USE 16"Φ column w/ (8) #5 Bars S.R. = 0.760

OR

USE 14" □ column w/ (8) #6 Bars S.R. = 0.857

* Transverse Reinf. (ACI 350 21.4.4)

$P_s = 0.12 (4500) / 60{,}000 = 0.009$

Spacing ⇛ $14"/4 = 3.5"$

$6(3/4") = 4.5"$

$S_x = 4 + \left(\frac{14 - 12}{3}\right) = 4.667"$

PER 10.9.3 $A_g = \pi \cdot 16^2/4 = 201 in^2$ $A_c = \pi \cdot 13.5^2/4 = 143\ in^2$

$P_s = 0.45 \left(\frac{201}{143} - 1\right) 4.5/60 = 0.0137$

Req'd pitch of #3 spiral = $0.0137 = \frac{0.11(\pi)(13.5")}{143 \cdot s}$ $S_{req'd} = 2.38"$

Req'd pitch of #4 spiral = $0.0137 = \frac{0.20(\pi)(13.5")}{143 \cdot s}$ $S_{req'd} = 4.32"$

Spacing of #3 hoops = $0.009 = \frac{0.11(\pi)(13.5")}{143 \cdot s}$ $S_{req'd} = 3.62"$

USE #4 spiral w/ 4" pitch or #3 hoops @ 3½" o.c.

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 22 AUG 2016, 1:47PM

Concrete Column

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

Description : Column Design - Circular

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 =	=	3,122.0 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 %

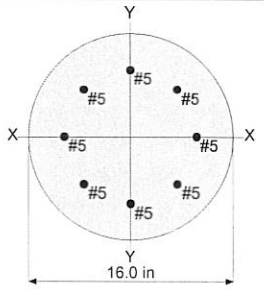
Overall Column Height = 18.0 ft
End Fixity: Top & Bottom Pinned

Brace condition for deflection (buckling) along columns :
X-X (width) axis :
Unbraced Length for X-X Axis buckling = 18.0 ft, K = 1.0
Y-Y (depth) axis :
Unbraced Length for X-X Axis buckling = 18.0 ft, K = 1.0

Column Cross Section

Column Dimensions : 16.0in Diameter, Column Edge to Rebar
Edge Cover = 2.50in

Column Reinforcing : 8 - #5 bars



Applied Loads

Entered loads are factored per load combinations specified by user.

Column self weight included : 3,769.91 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 18.0 ft above base, Xecc = 3.0in, Yecc = 3.0in, D = 54.20, S = 41.20, H = 35.30 k
BENDING LOADS . . .
Lat. Uniform Load creating Mx-x, E = 0.1620 k/ft

DESIGN SUMMARY

Load Combination +1.20D+0.50L+1.60S+1.60H
Location of max.above base 17.879 ft

Maximum Stress Ratio **0.760 : 1**
Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	191.964 k	φ * Pn =	253.337 k
Mu-x =	-53.902 k-ft	φ * Mn-x =	-70.966 k-ft
Mu-y =	-53.902 k-ft	φ * Mn-y =	70.966 k-ft
Mu Angle =	45.0 deg		
Mu at Angle =	76.229 k-ft	φMn at Angle =	100.351 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	1.815 k	Bottom along Y-Y	1.815 k
Top along X-X	2.438 k	Bottom along X-X	1.815 k

Maximum SERVICE Load Deflections . . .

Along Y-Y -0.1179 in at 10.510 ft above base
for load combination : +D+S+H

Along X-X -0.1179 in at 10.510 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	Bending Analysis k-ft δx	δx * Mux	δy	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.40D+1.60H	Actual	Actual	17.88	137.64	294.86	1.000	-32.87	1.000	-32.87	45.000	46.48	99.99	**0.465**

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 22 AUG 2016, 1:47PM

Concrete Column

ojects 2016\16194 - LPC - Upper System Tank\Engineering\Calculations\Other\16194_lpc - upper system tank.ec6
ENERCALC, INC. 1983-2016, Build:6.16.6.7, Ver:6.16.6.7

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

Description : Column Design - Circular

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	Bending Analysis k-ft δx	δx * Mux	δy	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.20D+0.50Lr+1.60L+1.60H	Actual	Actual	17.88	126.04	294.86	1.000	-30.18	1.000	-30.18	45.000	42.68	99.99	**0.427**
+1.20D+1.60L+0.50S+1.60H	Actual	Actual	17.88	146.64	294.86	1.000	-35.29	1.000	-35.29	45.000	49.91	99.99	**0.499**
+1.20D+1.60Lr+0.50L+1.60H	Actual	Actual	17.88	126.04	294.86	1.000	-30.18	1.000	-30.18	45.000	42.68	99.99	**0.427**
+1.20D+1.60Lr+0.50W+1.60H	Actual	Actual	17.88	126.04	294.86	1.000	-30.18	1.000	-30.18	45.000	42.68	99.99	**0.427**
+1.20D+0.50L+1.60S+1.60H	Actual	Actual	17.88	191.96	253.34	1.158	-53.90	1.158	-53.90	45.000	76.23	100.35	**0.760**
+1.20D+1.60S+0.50W+1.60H	Actual	Actual	17.88	191.96	253.34	1.158	-53.90	1.158	-53.90	45.000	76.23	100.35	**0.760**
+1.20D+0.50Lr+0.50L+W+1.60H	Actual	Actual	17.88	126.04	294.86	1.000	-30.18	1.000	-30.18	45.000	42.68	99.99	**0.427**
+1.20D+0.50L+0.50S+W+1.60H	Actual	Actual	17.88	146.64	294.86	1.000	-35.29	1.000	-35.29	45.000	49.91	99.99	**0.499**
+1.20D+0.50L+0.20S+E+1.60H	Actual	Actual	17.88	134.28	230.99	1.509	-48.34	1.000	-32.22	45.000	58.10	100.03	**0.581**
+0.90D+W+0.90H	Actual	Actual	17.88	83.94	297.46	1.000	-20.00	1.000	-20.00	45.000	28.29	99.92	**0.283**
+0.90D+E+0.90H	Actual	Actual	17.88	83.94	262.93	1.267	-25.12	1.000	-20.00	45.000	32.11	100.39	**0.320**

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	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+L+H	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+Lr+H	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+S+H	1.815	1.815 k	1.815	1.815 k	134.470 k
+D+0.750Lr+0.750L+H	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+0.750L+0.750S+H	1.672	1.672 k	1.672	1.672 k	124.170 k
+D+0.60W+H	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+0.70E+H	1.243	1.243 k	0.222	2.264 k	93.270 k
+D+0.750Lr+0.750L+0.450W+H	1.243	1.243 k	1.243	1.243 k	93.270 k
+D+0.750L+0.750S+0.450W+H	1.672	1.672 k	1.672	1.672 k	124.170 k
+D+0.750L+0.750S+0.5250E+H	1.672	1.672 k	0.907	2.438 k	124.170 k
+0.60D+0.60W+0.60H	0.746	0.746 k	0.746	0.746 k	55.962 k
+0.60D+0.70E+0.60H	0.746	0.746 k	0.275	1.766 k	55.962 k
D Only	0.753	0.753 k	0.753	0.753 k	57.970 k
Lr Only		k		k	k
L Only		k		k	k
S Only	0.572	0.572 k	0.572	0.572 k	41.200 k
W Only		k		k	k
E Only		k	1.458	1.458 k	k
H Only	0.490	0.490 k	0.490	0.490 k	35.300 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		k-ft		k-ft
+D+L+H		k-ft		k-ft
+D+Lr+H		k-ft		k-ft
+D+S+H		k-ft		k-ft
+D+0.750Lr+0.750L+H		k-ft		k-ft
+D+0.750L+0.750S+H		k-ft		k-ft
+D+0.60W+H		k-ft		k-ft
+D+0.70E+H		k-ft		k-ft
+D+0.750Lr+0.750L+0.450W+H		k-ft		k-ft
+D+0.750L+0.750S+0.450W+H		k-ft		k-ft
+D+0.750L+0.750S+0.5250E+H		k-ft		k-ft
+0.60D+0.60W+0.60H		k-ft		k-ft
+0.60D+0.70E+0.60H		k-ft		k-ft
D Only		k-ft		k-ft
Lr Only		k-ft		k-ft
L Only		k-ft		k-ft
S Only		k-ft		k-ft
W Only		k-ft		k-ft
E Only		k-ft		k-ft
H Only		k-ft		k-ft

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 22 AUG 2016, 1:47PM

Concrete Column

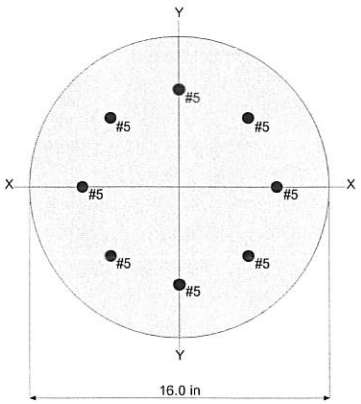
Lic. # : KW-06002489 — Licensee : ARW ENGINEERS

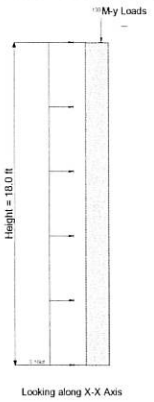
Description : Column Design - Circular

Maximum Deflections for Load Combinations

Load Combination	Max. X-X Deflection		Distance		Max. Y-Y Deflection		Distance	
+D+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+L+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+Lr+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+S+H	-0.1179	in	10.510	ft	-0.118	in	10.510	ft
+D+0.750Lr+0.750L+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+0.750L+0.750S+H	-0.1086	in	10.510	ft	-0.109	in	10.510	ft
+D+0.60W+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+0.70E+H	-0.0807	in	10.510	ft	-0.055	in	11.114	ft
+D+0.750Lr+0.750L+0.450W+H	-0.0807	in	10.510	ft	-0.081	in	10.510	ft
+D+0.750L+0.750S+0.450W+H	-0.1086	in	10.510	ft	-0.109	in	10.510	ft
+D+0.750L+0.750S+0.5250E+H	-0.1086	in	10.510	ft	-0.089	in	10.752	ft
+0.60D+0.60W+0.60H	-0.0484	in	10.510	ft	-0.048	in	10.510	ft
+0.60D+0.70E+0.60H	-0.0484	in	10.510	ft	-0.023	in	12.081	ft
D Only	-0.0489	in	10.510	ft	-0.049	in	10.510	ft
Lr Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
L Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
S Only	-0.0372	in	10.510	ft	-0.037	in	10.510	ft
W Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
E Only	0.0000	in	0.000	ft	0.039	in	9.060	ft
H Only	-0.0318	in	10.510	ft	-0.032	in	10.510	ft

Sketches





Looking along X-X Axis

Looking along Y-Y Axis

Interaction Diagrams

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

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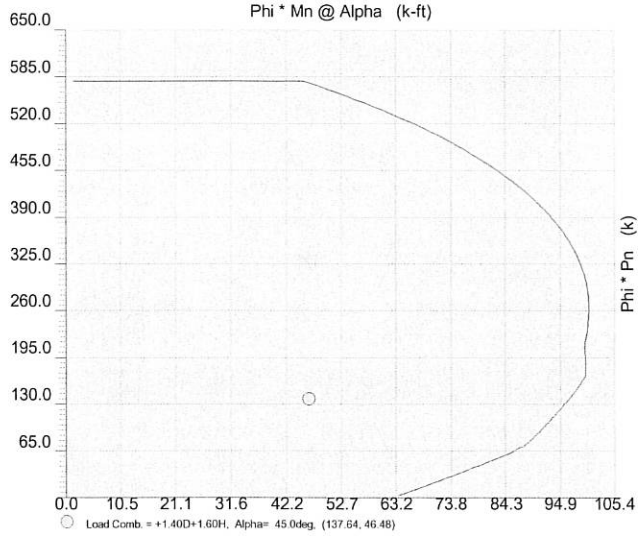
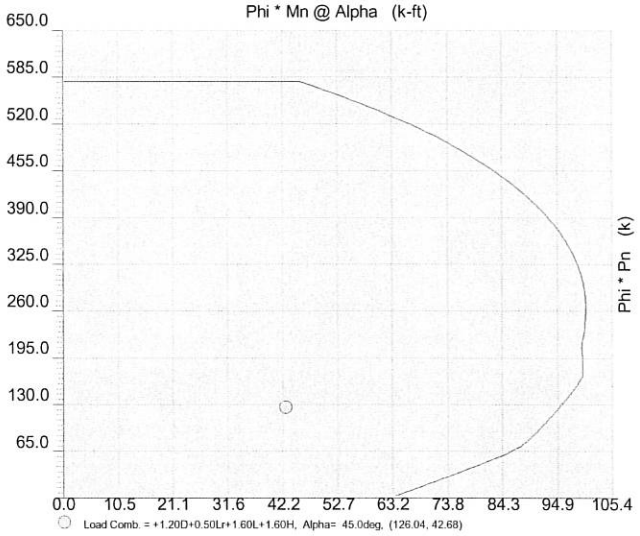
Concrete Column

Description : Column Design - Circular

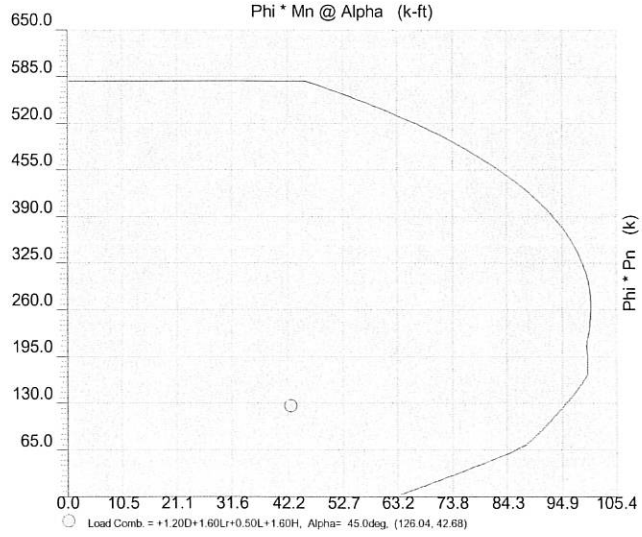
Concrete Column P-M Interaction Diagram



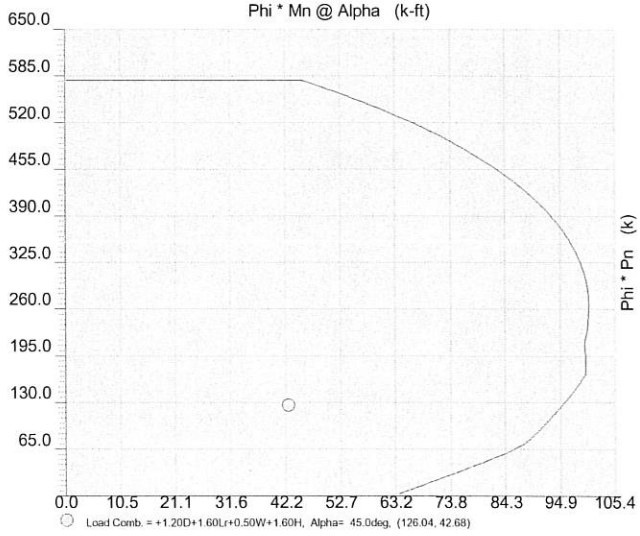
Concrete Column P-M Interaction Diagram



Concrete Column P-M Interaction Diagram



Concrete Column P-M Interaction Diagram



ARW Engineers
1594 W Park Circle
Ogden, UT 84404

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Concrete Column

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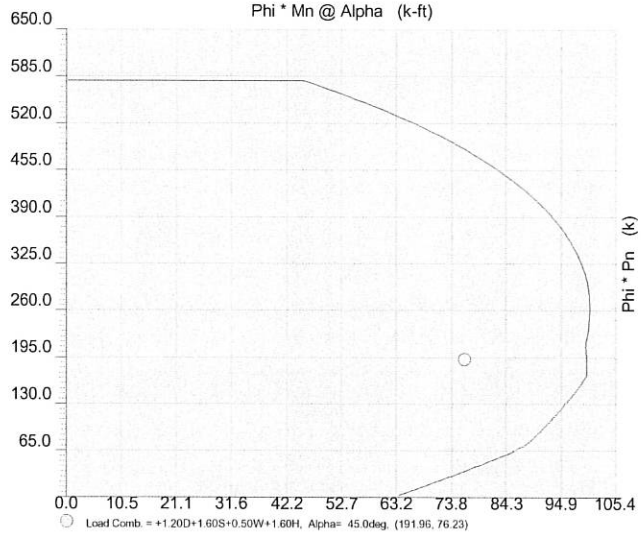
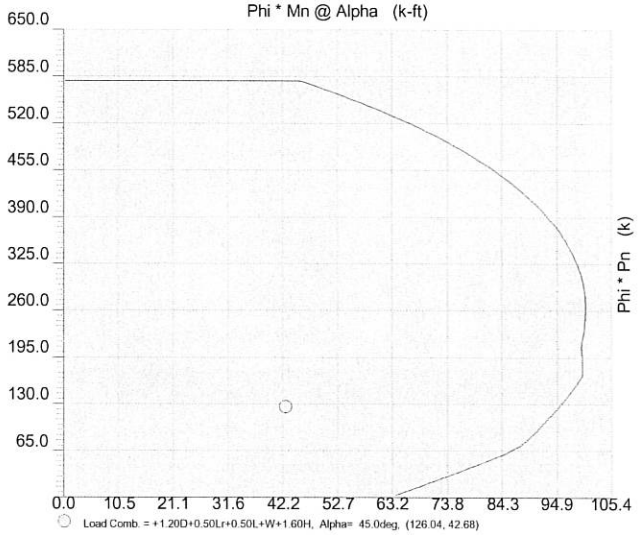
Description : Column Design - Circular

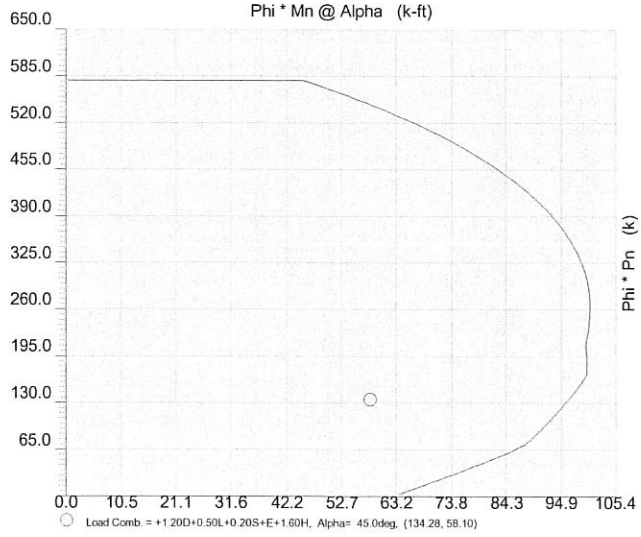
Concrete Column P-M Interaction Diagram
Phi * Mn @ Alpha (k-ft)



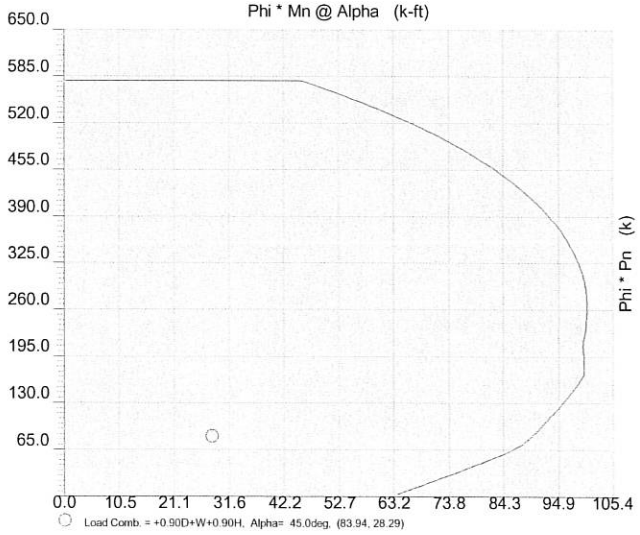
Concrete Column P-M Interaction Diagram
Phi * Mn @ Alpha (k-ft)



Concrete Column P-M Interaction Diagram
Phi * Mn @ Alpha (k-ft)



Concrete Column P-M Interaction Diagram
Phi * Mn @ Alpha (k-ft)



ARW Engineers
1594 W Park Circle
Ogden, UT 84404

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Project ID:

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Concrete Column

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

Description : Column Design - Square

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 =	=	3,122.0 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 %

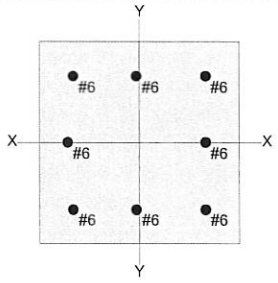
Overall Column Height = 18.0 ft
End Fixity: Top & Bottom Pinned

Brace condition for deflection (buckling) along columns :
X-X (width) axis :
Unbraced Length for X-X Axis buckling = 18.0 ft, K = 1.0
Y-Y (depth) axis :
Unbraced Length for X-X Axis buckling = 18.0 ft, K = 1.0

Column Cross Section

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

Column Reinforcing : 4 - #6 bars @ corners,, 1.0 - #6 bars top & bottom between corner bars, 1.0 - #6 bars left & right between corner bars



Applied Loads

Entered loads are factored per load combinations specified by user.

Column self weight included : 3,675.0 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 18.0 ft above base, Xecc = 3.0in, Yecc = 3.0in, D = 54.20, S = 41.20, H = 35.30 k
BENDING LOADS . . .
Lat. Uniform Load creating Mx-x, E = 0.1620 k/ft

DESIGN SUMMARY

Load Combination +1.20D+0.50L+1.60S+1.60H
Location of max.above base 17.879 ft

Maximum Stress Ratio 0.857 : 1
Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	191.850 k	φ * Pn =	224.157 k
Mu-x =	-54.118 k-ft	φ * Mn-x =	-62.840 k-ft
Mu-y =	-54.118 k-ft	φ * Mn-y =	63.483 k-ft
Mu Angle =	45.0 deg		
Mu at Angle =	76.534 k-ft	φMn at Angle =	89.329 k-ft

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

Column Capacities . . .

Pnmax : Nominal Max. Compressive Axial Capacity	947.44 k
Pnmin : Nominal Min. Tension Axial Capacity	-211.20 k
φ Pn, max : Usable Compressive Axial Capacity	492.667 k
φ Pn, min : Usable Tension Axial Capacity	-137.280 k

Maximum SERVICE Load Reactions . .

Top along Y-Y	1.815 k	Bottom along Y-Y	1.815 k
Top along X-X	2.438 k	Bottom along X-X	1.815 k

Maximum SERVICE Load Deflections . . .

Along Y-Y -0.1184 in at 10.510 ft above base
for load combination : +D+S+H

Along X-X -0.1184 in at 10.510 ft above base
for load combination : +D+S+H

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

ρ : % Reinforcing	1.796 % Rebar % Ok
Reinforcing Area	3.520 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	Bending Analysis k-ft δx	δx * Mux	δy	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.40D+1.60H	Actual	Actual	17.88	137.51	263.16	1.000	-32.87	1.000	-32.87	45.000	46.48	88.61	**0.524**

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

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Concrete Column

Description : Column Design - Square

Governing Load Combination Results

Governing Factored Load Combination	Moment X-X	Moment Y-Y	Dist. from base ft	Axial Load k Pu	φ * Pn	Bending Analysis k-ft δx	δx * Mux	δy	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.20D+0.50Lr+1.60L+1.60H	Actual	Actual	17.88	125.93	260.68	1.000	-30.18	1.000	-30.18	45.000	42.68	88.69	**0.481**
+1.20D+1.60L+0.50S+1.60H	Actual	Actual	17.88	146.53	260.68	1.000	-35.29	1.000	-35.29	45.000	49.91	88.69	**0.563**
+1.20D+1.60Lr+0.50L+1.60H	Actual	Actual	17.88	125.93	260.68	1.000	-30.18	1.000	-30.18	45.000	42.68	88.69	**0.481**
+1.20D+1.60Lr+0.50W+1.60H	Actual	Actual	17.88	125.93	260.68	1.000	-30.18	1.000	-30.18	45.000	42.68	88.69	**0.481**
+1.20D+0.50L+1.60S+1.60H	Actual	Actual	17.88	191.85	224.16	1.163	-54.12	1.163	-54.12	45.000	76.53	89.33	**0.857**
+1.20D+1.60S+0.50W+1.60H	Actual	Actual	17.88	191.85	224.16	1.163	-54.12	1.163	-54.12	45.000	76.53	89.33	**0.857**
+1.20D+0.50Lr+0.50L+W+1.60H	Actual	Actual	17.88	125.93	260.68	1.000	-30.18	1.000	-30.18	45.000	42.68	88.69	**0.481**
+1.20D+0.50L+0.50S+W+1.60H	Actual	Actual	17.88	146.53	260.68	1.000	-35.29	1.000	-35.29	45.000	49.91	88.69	**0.563**
+1.20D+0.50L+0.20S+E+1.60H	Actual	Actual	17.88	134.17	205.74	1.512	-48.44	1.000	-32.22	45.000	58.18	89.26	**0.652**
+0.90D+W+0.90H	Actual	Actual	17.88	83.86	263.16	1.000	-20.00	1.000	-20.00	45.000	28.29	88.61	**0.319**
+0.90D+E+0.90H	Actual	Actual	17.88	83.86	233.15	1.268	-25.15	1.000	-20.00	45.000	32.13	89.26	**0.360**

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	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+L+H	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+Lr+H	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+S+H	1.815	1.815 k	1.815	1.815 k	134.375 k
+D+0.750Lr+0.750L+H	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+0.750L+0.750S+H	1.672	1.672 k	1.672	1.672 k	124.075 k
+D+0.60W+H	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+0.70E+H	1.243	1.243 k	0.222	2.264 k	93.175 k
+D+0.750Lr+0.750L+0.450W+H	1.243	1.243 k	1.243	1.243 k	93.175 k
+D+0.750L+0.750S+0.450W+H	1.672	1.672 k	1.672	1.672 k	124.075 k
+D+0.750L+0.750S+0.5250E+H	1.672	1.672 k	0.907	2.438 k	124.075 k
+0.60D+0.60W+0.60H	0.746	0.746 k	0.746	0.746 k	55.905 k
+0.60D+0.70E+0.60H	0.746	0.746 k	0.275	1.766 k	55.905 k
D Only	0.753	0.753 k	0.753	0.753 k	57.875 k
Lr Only		k		k	k
L Only		k		k	k
S Only	0.572	0.572 k	0.572	0.572 k	41.200 k
W Only		k		k	k
E Only		k	1.458	1.458 k	k
H Only	0.490	0.490 k	0.490	0.490 k	35.300 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		k-ft		k-ft
+D+L+H		k-ft		k-ft
+D+Lr+H		k-ft		k-ft
+D+S+H		k-ft		k-ft
+D+0.750Lr+0.750L+H		k-ft		k-ft
+D+0.750L+0.750S+H		k-ft		k-ft
+D+0.60W+H		k-ft		k-ft
+D+0.70E+H		k-ft		k-ft
+D+0.750Lr+0.750L+0.450W+H		k-ft		k-ft
+D+0.750L+0.750S+0.450W+H		k-ft		k-ft
+D+0.750L+0.750S+0.5250E+H		k-ft		k-ft
+0.60D+0.60W+0.60H		k-ft		k-ft
+0.60D+0.70E+0.60H		k-ft		k-ft
D Only		k-ft		k-ft
Lr Only		k-ft		k-ft
L Only		k-ft		k-ft
S Only		k-ft		k-ft
W Only		k-ft		k-ft
E Only		k-ft		k-ft
H Only		k-ft		k-ft

Footing Design

DL: $54.2^k \cdot 1000 + 150\,pcf\,(16''/12)^2/4 \cdot \pi \cdot 18' = 58.0^k$

SL: 41.2^k

Soil: 35.3^k

* SEE ENERCALC SOLUTION

USE F 6.5 X 18" thick w/ (6) #6 BARS Each Direction

Continuous Wall Footing

DL: $115\,psf\,(17'\text{-}8''/2) + 150\,pcf\,(12''/12)(17'\text{-}0'') = 3570\,plf$

SL: $100\,psf\,(17'\text{-}8''/2) = 885\,plf$

Soil: $75\,psf\,(17'\text{-}8''/2) = 665\,plf$

USE 3'-0" X 16" Footing w/ (3) #6 BARS

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 23 AUG 2016, 9:29AM

General Footing

Description : 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

f'c : Concrete 28 day strength	=	3.0 ksi
fy : Rebar Yield	=	60.0 ksi
Ec : Concrete Elastic Modulus	=	3,122.0 ksi
Concrete Density	=	145.0 pcf
φ Values Flexure	=	0.90
Shear	=	0.750

Analysis Settings

Min Steel % Bending Reinf.	=	
Min Allow % Temp Reinf.	=	0.00180
Min. Overturning Safety Factor	=	1.0 : 1
Min. Sliding Safety Factor	=	1.0 : 1
Add Ftg Wt for Soil Pressure	:	Yes
Use ftg wt for stability, moments & shears	:	Yes
Add Pedestal Wt for Soil Pressure	:	No
Use Pedestal wt for stability, mom & shear	:	No

Soil Design Values

Allowable Soil Bearing	=	4.0 ksf
Increase Bearing By Footing Weight	=	No
Soil Passive Resistance (for Sliding)	=	250.0 pcf
Soil/Concrete Friction Coeff.	=	0.30

Increases based on footing Depth

Footing base depth below soil surface	=	ft
Allow press. increase per foot of depth	=	ksf
when footing base is below	=	ft

Increases based on footing plan dimension

Allowable pressure increase per foot of depth	=	ksf
when max. length or width is greater than	=	ft

Dimensions

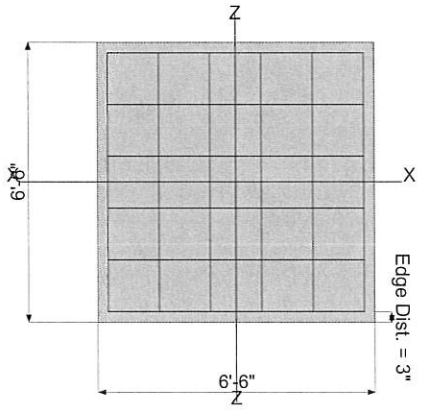
Width parallel to X-X Axis	=	6.50 ft
Length parallel to Z-Z Axis	=	6.50 ft
Footing Thickness	=	18.0 in

Pedestal dimensions...

px : parallel to X-X Axis	=	14.0 in
pz : parallel to Z-Z Axis	=	14.0 in
Height	=	in

Rebar Centerline to Edge of Concrete...

at Bottom of footing	=	3.0 in



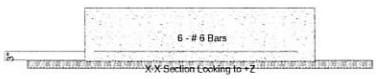
Reinforcing

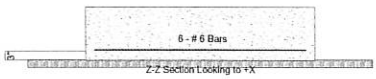
Bars parallel to X-X Axis

Number of Bars	=	6.0
Reinforcing Bar Size	=	# 6

Bars parallel to Z-Z Axis

Number of Bars	=	6.0
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	=	58.0			41.20			35.30	k
OB : Overburden	=								ksf
M-xx	=								k-ft
M-zz	=								k-ft
V-x	=								k
V-z	=								k

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 23 AUG 2016, 9:29AM

General Footing

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

Description : Column Footing

DESIGN SUMMARY

Design OK

	Min. Ratio	Item	Applied	Capacity	Governing Load Combination
PASS	0.8503	Soil Bearing	3.401 ksf	4.0 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	0.6053	Z Flexure (+X)	16.154 k-ft	26.688 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.6053	Z Flexure (-X)	16.154 k-ft	26.688 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.6053	X Flexure (+Z)	16.154 k-ft	26.688 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.6053	X Flexure (-Z)	16.154 k-ft	26.688 k-ft	+1.20D+0.50L+1.60S+1.60H
PASS	0.4328	1-way Shear (+X)	35.556 psi	82.158 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4328	1-way Shear (-X)	35.556 psi	82.158 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4328	1-way Shear (+Z)	35.556 psi	82.158 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.4328	1-way Shear (-Z)	35.556 psi	82.158 psi	+1.20D+0.50L+1.60S+1.60H
PASS	0.5813	2-way Punching	95.510 psi	164.317 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	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+L+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+Lr+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+S+H	4.0	n/a	0.0	3.401	3.401	n/a	n/a	0.850
X-X, +D+0.750Lr+0.750L+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+0.750L+0.750S+H	4.0	n/a	0.0	3.157	3.157	n/a	n/a	0.789
X-X, +D+0.60W+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+0.70E+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+0.750Lr+0.750L+0.450W+H	4.0	n/a	0.0	2.426	2.426	n/a	n/a	0.607
X-X, +D+0.750L+0.750S+0.450W+H	4.0	n/a	0.0	3.157	3.157	n/a	n/a	0.789
X-X, +D+0.750L+0.750S+0.5250E+H	4.0	n/a	0.0	3.157	3.157	n/a	n/a	0.789
X-X, +0.60D+0.60W+0.60H	4.0	n/a	0.0	1.455	1.455	n/a	n/a	0.364
X-X, +0.60D+0.70E+0.60H	4.0	n/a	0.0	1.455	1.455	n/a	n/a	0.364
Z-Z, +D+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+L+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+Lr+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+S+H	4.0	0.0	n/a	n/a	n/a	3.401	3.401	0.850
Z-Z, +D+0.750Lr+0.750L+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+0.750L+0.750S+H	4.0	0.0	n/a	n/a	n/a	3.157	3.157	0.789
Z-Z, +D+0.60W+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+0.70E+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+0.750Lr+0.750L+0.450W+H	4.0	0.0	n/a	n/a	n/a	2.426	2.426	0.607
Z-Z, +D+0.750L+0.750S+0.450W+H	4.0	0.0	n/a	n/a	n/a	3.157	3.157	0.789
Z-Z, +D+0.750L+0.750S+0.5250E+H	4.0	0.0	n/a	n/a	n/a	3.157	3.157	0.789
Z-Z, +0.60D+0.60W+0.60H	4.0	0.0	n/a	n/a	n/a	1.455	1.455	0.364
Z-Z, +0.60D+0.70E+0.60H	4.0	0.0	n/a	n/a	n/a	1.455	1.455	0.364

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				

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 22 AUG 2016, 3:05PM

Wall Footing

ojects 2016\16194 - LPC - Upper System Tank\Engineering\Calculations\Other\16194_lpc - upper system tank.ec6
ENERCALC, INC. 1983-2016, Build:6.16.6.7, Ver:6.16.6.7

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

Description : Continuous Wall 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

f'c : Concrete 28 day strength	=	4.50 ksi
fy : Rebar Yield	=	60.0 ksi
Ec : Concrete Elastic Modulus	=	3,122.0 ksi
Concrete Density	=	145.0 pcf
φ Values Flexure	=	0.90
Shear	=	0.750

Analysis Settings

Min Steel % Bending Reinf.	=	
Min Allow % Temp Reinf.	=	0.00180
Min. Overturning Safety Factor	=	1.0 : 1
Min. Sliding Safety Factor	=	1.0 : 1
AutoCalc Footing Weight as DL	:	Yes

Soil Design Values

Allowable Soil Bearing	=	4.0 ksf
Increase Bearing By Footing Weight	=	No
Soil Passive Resistance (for Sliding)	=	250.0 pcf
Soil/Concrete Friction Coeff.	=	0.30

Increases based on footing Depth

Reference Depth below Surface	=	0.0 ft
Allow. Pressure Increase per foot of depth	=	0.0 ksf
when base footing is below	=	0.0 ft

Increases based on footing Width

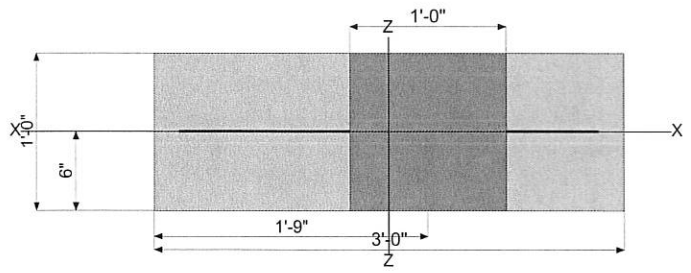
Allow. Pressure Increase per foot of width	=	0.0 ksf
when footing is wider than	=	0.0 ft

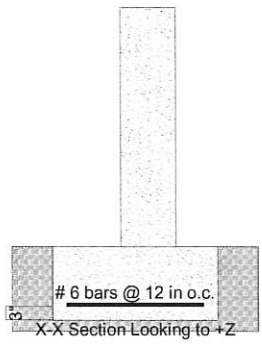
Adjusted Allowable Bearing Pressure = 4.0 ksf

Dimensions

Footing Width	=	3.0 ft	Footing Thickness	=	16.0 in	Bars along X-X Axis	
Wall Thickness	=	12.0 in	Rebar Centerline to Edge of Concrete...			Bar spacing	= 12.00
Wall center offset from center of footing	=	3 in	at Bottom of footing	=	3.0 in	Reinforcing Bar Size	= # 6

Reinforcing





Applied Loads

		D	Lr	L	S	W	E	H	
P : Column Load	=	3.570	0.0	0.0	0.8850	0.0	0.0	0.6650	k
OB : Overburden	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ksf
V-x	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	k
M-zz	=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	k-ft

Vx applied = 0.0 in above top of footing

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 22 AUG 2016, 3:05PM

Wall Footing

Description : Continuous Wall Footing

DESIGN SUMMARY

Design OK

	Factor of Safety	Item	Applied	Capacity	Governing Load Combination
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	Uplift	0.0 k	0.0 k	No Uplift

	Utilization Ratio	Item	Applied	Capacity	Governing Load Combination
PASS	0.6855	Soil Bearing	2.742 ksf	4.0 ksf	+D+S+H
PASS	0.03827	Z Flexure (+X)	0.9634 k-ft	25.171 k-ft	+1.20D+0.50L+1.60S+1
PASS	0.03060	Z Flexure (-X)	0.7701 k-ft	25.171 k-ft	+0.90D+E+0.90H
PASS	n/a	1-way Shear (+X)	0.0 psi	100.623 psi	n/a
PASS	0.02535	1-way Shear (-X)	2.550 psi	100.623 psi	+1.20D+0.50L+1.60S+1

Detailed Results

Soil Bearing

Rotation Axis & Load Combination...	Gross Allowable	Xecc	Actual Soil Bearing Stress -X	Actual Soil Bearing Stress +X	Actual / Allowable Ratio
, +D+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+L+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+Lr+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+S+H	4.0 ksf	2.695 in	1.058 ksf	2.742 ksf	0.686
, +D+0.750Lr+0.750L+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+0.750L+0.750S+H	4.0 ksf	2.682 in	1.021 ksf	2.632 ksf	0.658
, +D+0.60W+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+0.70E+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+0.750Lr+0.750L+0.450W+H	4.0 ksf	2.639 in	0.9086 ksf	2.301 ksf	0.575
, +D+0.750L+0.750S+0.450W+H	4.0 ksf	2.682 in	1.021 ksf	2.632 ksf	0.658
, +D+0.750L+0.750S+0.5250E+H	4.0 ksf	2.682 in	1.021 ksf	2.632 ksf	0.658
, +0.60D+0.60W+0.60H	4.0 ksf	2.639 in	0.5451 ksf	1.381 ksf	0.345
, +0.60D+0.70E+0.60H	4.0 ksf	2.639 in	0.5451 ksf	1.381 ksf	0.345

Overturning Stability

Units : k-ft

Rotation Axis & Load Combination...	Overturning Moment	Resisting Moment	Stability Ratio	Status

Footing Has NO Overturning

Sliding Stability

Force Application Axis Load Combination...	Sliding Force	Resisting Force	Sliding SafetyRatio	Status

Footing Has NO Sliding

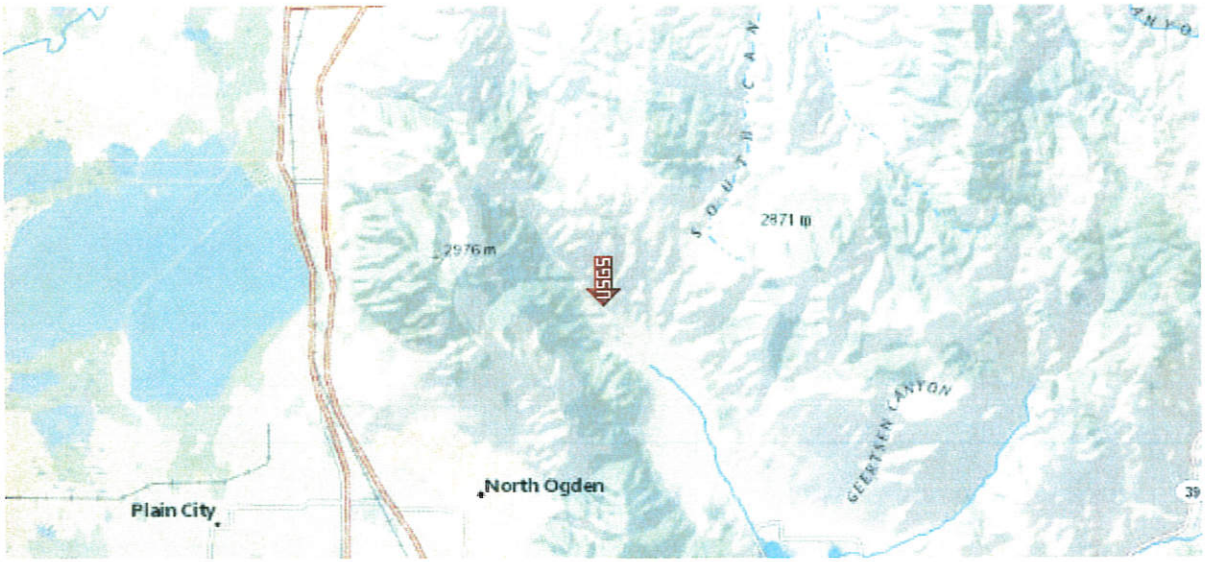
Footing Flexure

Flexure Axis & Load Combination	Mu k-ft	Which Side ?	Tension @ Bot. or Top ?	As Req'd in^2	Gvrn. As in^2	Actual As in^2	Phi*Mn k-ft	Status
, +1.40D+1.60H	1.22	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.40D+1.60H	0.881	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50Lr+1.60L+1.60H	1.071	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50Lr+1.60L+1.60H	0.7753	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60L+0.50S+1.60H	1.145	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60L+0.50S+1.60H	0.8341	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60Lr+0.50L+1.60H	1.071	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60Lr+0.50L+1.60H	0.7753	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60Lr+0.50W+1.60H	1.071	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60Lr+0.50W+1.60H	0.7753	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50L+1.60S+1.60H	1.307	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50L+1.60S+1.60H	0.9634	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60S+0.50W+1.60H	1.307	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+1.60S+0.50W+1.60H	0.9634	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50Lr+0.50L+W+1.60H	1.071	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50Lr+0.50L+W+1.60H	0.7753	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50L+0.50S+W+1.60H	1.145	-X	Bottom	0.3456	Min Temp %	0.44	25.171	OK
, +1.20D+0.50L+0.50S+W+1.60H	0.8341	+X	Bottom	0.3456	Min Temp %	0.44	25.171	OK

USGS Design Maps Summary Report

User–Specified Input

Report Title	Liberty Upper System Tank Wed August 17, 2016 16:17:16 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	41.3864°N, 111.9022°W
Site Soil Classification	Site Class B – "Rock"
Risk Category	I/II/III

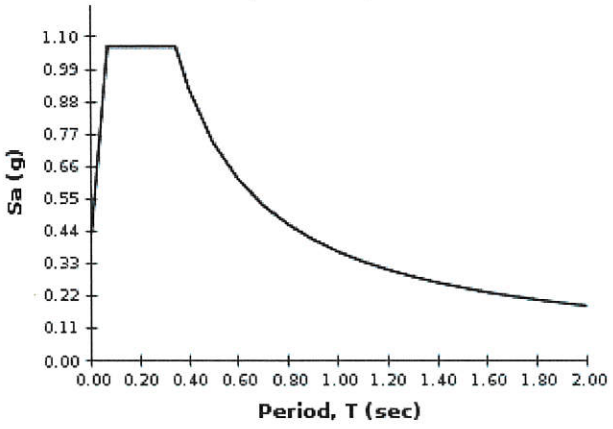


USGS–Provided Output

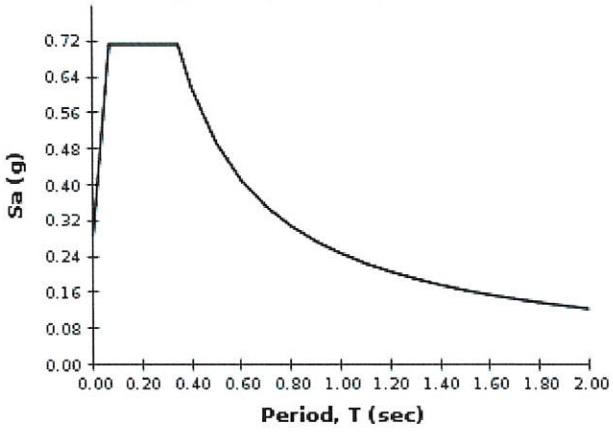
S_S =	1.068 g	S_{MS} =	1.068 g	S_{DS} =	0.712 g
S_1 =	0.370 g	S_{M1} =	0.370 g	S_{D1} =	0.247 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

MCE_R Response Spectrum



Design Response Spectrum



For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Project Name LPC - Upper System Tank
Project # 16194
Prepared By WWY
Date 8/23/2016

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

ENGINEERS
structural consultants

D_{tank}	53	ft
H_L	16	ft
g	32.17	ft/s^2
λ	9.758527418	
T_C	4.687416198	s
S_{D1}	0.247	g
S_{DS}	0.712	g
T_S	0.346910112	s
C_C	0.077772167	
I	1.25	
d_{max}	2.576203046	ft

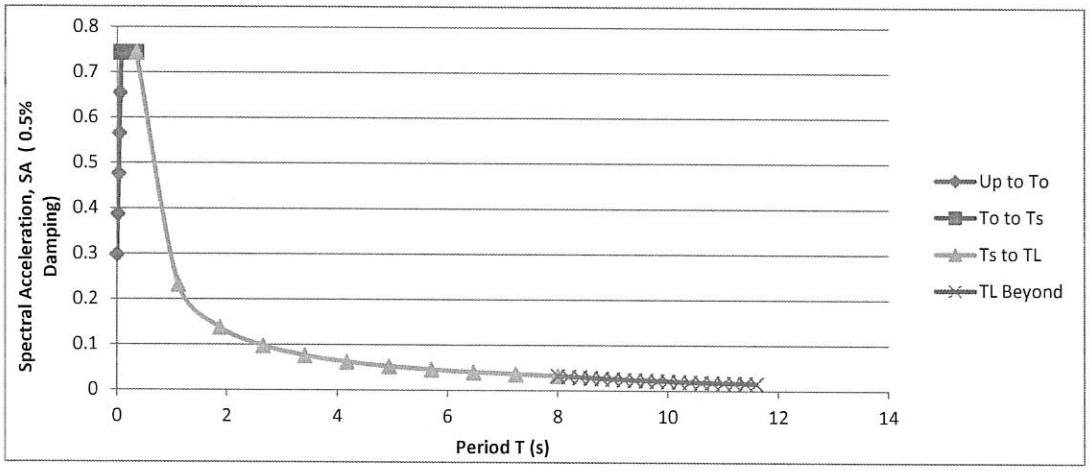
Required Freeboard

Tank Volume	255802	Gallons
Ht to Water	15.5	ft

New H_L	15.5	ft
New d_f	0.5	ft

Height to Liquid after Freeboard Check (IF desired to change from above)

h_n	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	0.069382022	s	Per ASCE 7
T_L	8	s	Per ASCE 7 (fig 22-15)
S_a	0.456457993	g	For periods less than T_o
S_a	0.712	g	For periods >= to T_o and <= to T_s



Find Pressure at Roof to Shell interface from insufficient freeboard depth.

SA (T_C)	0.052694275	g	Spectral Acceleration at Tc
Theta	3.01636981	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}	1470.788961	ft^3	Empty Volume of tank above water
d	1.396398298	ft	Vertical displacement of liquid surface
d_f/d	0.358064029		
h_r/d	0.358064029		
X_f/R	0.95		Fig 6 from "Earthquake Induced Sloshing in Tanks with insufficient Freeboard"
X_f	25.175	ft	
ρ	1.94	$slugs/ft^3$	mass density of liquid
P_{max}	32.21	psf	Weight of Roof is heavier, therefore ok
F_{max}	405.48	plf	#5 Radial Dowels @ 16" o.c. okay (Roof Slab to Wall)

Slab wt = 150 pcf · 8"/12 · 0.6 = 60 psf

$P_n/\Omega = \frac{60\,ksi \cdot 0.31\,in^2 \cdot 12"/16}{1.67} = 8353\ plf$

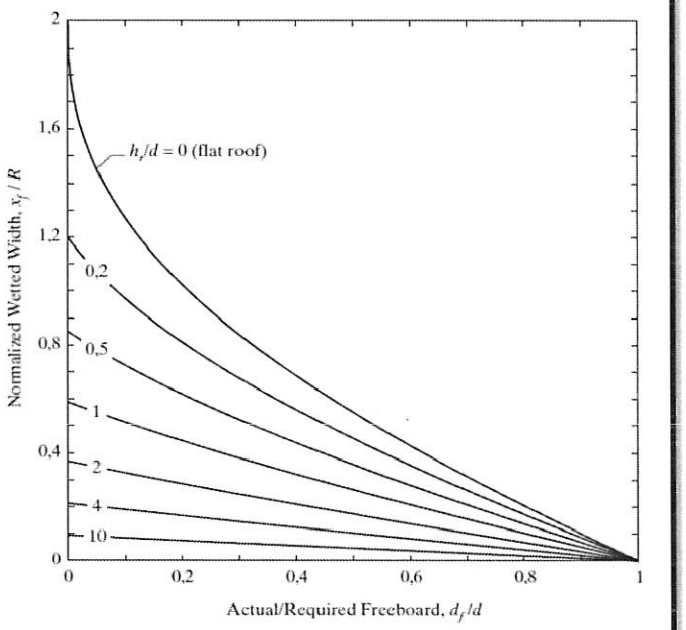


Fig. 6: Cone roof tank. Normalized wetted width of tank roof x_f/R as a function of actual/required freeboard d_f/d and normalized roof height h_r/d

Weight

D/H_L	3.419354839				
Wi/W_L	0.33	PCA EB219 fig 4-4 (b)			
Wc/W_L	0.61	PCA EB219 fig 4-4 (b)			
W_L	2223	kips	Weight Of Water		
Wi	734	kips	Impulsive Weight		
Wc	1356	kips	Convective Weight		
Tw	12	inches	Wall Thickness	D_{outer}	55.00 ft
Tr	8	inches	Roof Thickness		
W_W	407	kips	Weight of Walls		
W_R	238	kips	Weight of Roof		

Period

Cw	0.142	PCA EB219 fig 4-10	
C_L	0.28		
Ec	3605	ksi	Elastic Modulus of Concrete
ρ_c	4.66	#-s/ft^4	Mass Density of Concrete
ω_I	187.8341836	rad/s	
T_I	0.03	s	

Base Shear

R	1.5	Response Modification Factor	
C_{si}	0.59		
$C_{si\ (min)}$	6.15		
C_{sc}	0.59		
$C_{sc\ (min)}$	0.04		
Vi	1022	kips	Impulsive Base Shear
Vc	74	kips	Convective Base Shear
V_T	1025	kips	Total Base Shear

Overturning Moment

h_i/H_L	0.375	PCA EB219	fig 4-5 (b)
h_c/H_L	0.54	PCA EB219	fig 4-5 (b)
h_i	5.8125	ft	
h_c	8.37	ft	
h_w	8	ft	
M_i	6718	kip ft	Impulsive
M_c	6733	kip ft	Convective (Per ACI 350)
M_T	9511	kip ft	Total

Overall Stability Check

Sliding (Neglecting Backfill)		
Weight of tank w/out contents:		
Walls	407	kips
Roof	238	kips
Columns	30	kips
Base Slab	229	kips
Water	2223	kips
Total Weight	3127	kips
Friction Coeff	0.41	
Base Shear	1025	
Safety Factor	1.25	ok
Overturning		
OTM	9511	kip ft
RM	82856	kip ft
Safety Factor	8.7	ok

Design of Walls for In-Plane Loading

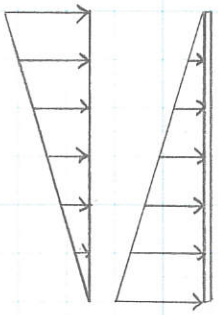
V_u	1025	kips	Base Shear
V_c	9.8	kips/ft	Shear in wall
α_c	3	See ACI 318 eqn 21-7	
ρ_t	0.006111	See ACI 318 eqn 21-7	#6 at 12" oc EF
φVn	60.1	kips/ft	ok

$\phi V_n = 60.1 K/ft \supset V_c = 9.8 K/ft \therefore OK$

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

Seismic Forces on Empty Tank

Seismic Active Pressure = 46 pcf · 16' = 736 psf



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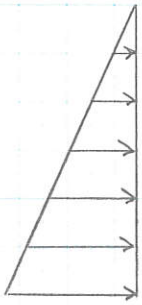


At-Rest Pressure = 57 pcf · 16' = 912 psf

W =

M_{max} = 1.649 K-ft @ 7.863'

* SEE ENERCALC SOLUTION

* Equivalent W

$$1.649 \text{ K-ft} = \frac{\frac{w(16)}{2} \cdot 7.863' \left(16^2 - 7.863^2\right)}{3 \cdot 16^2}$$

W = 104 pcf

↑

This is used in spreadsheet

ARW Engineers
1594 W Park Circle
Ogden, UT 84404

Project Title:
Engineer:
Project Descr:

Project ID:

Printed: 23 AUG 2016, 8:32AM

Steel Beam

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

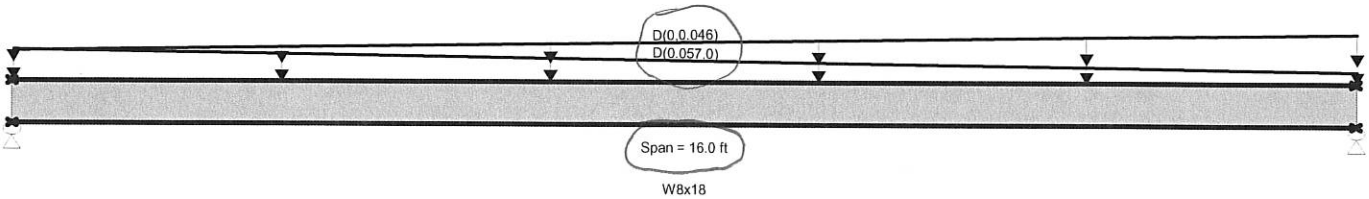
Description : Maximum Moment

CODE REFERENCES

Calculations per AISC 360-10, IBC 2012, ASCE 7-10
Load Combination Set : ASCE 7-10

Material Properties

Analysis Method :	Allowable Strength Design	Fy : Steel Yield :	50.0 ksi
Beam Bracing :	Beam is Fully Braced against lateral-torsional buckling	E: Modulus :	29,000.0 ksi
Bending Axis :	Major Axis Bending		



Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Beam self weight NOT internally calculated and added
Load for Span Number 1
Varying Uniform Load : D(S,E) = 0.0570->0.0 k/ft, Extent = 0.0 -->> 16.0 ft, Trib Width = 1.0 ft
Varying Uniform Load : D(S,E) = 0.0->0.0460 k/ft, Extent = 0.0 -->> 16.0 ft, Trib Width = 1.0 ft

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio =	0.039 : 1	Maximum Shear Stress Ratio =	0.011 : 1
Section used for this span	W8x18	Section used for this span	W8x18
Ma : Applied	1.649 k-ft	Va : Applied	0.4267 k
Mn / Omega : Allowable	42.415 k-ft	Vn/Omega : Allowable	37.444 k
Load Combination	+D+H	Load Combination	+D+H
Location of maximum on span	7.863ft	Location of maximum on span	0.000 ft
Span # where maximum occurs	Span # 1	Span # where maximum occurs	Span # 1

Maximum Deflection

Max Downward Transient Deflection	0.000 in	Ratio =	0 <360
Max Upward Transient Deflection	0.000 in	Ratio =	0 <360
Max Downward Total Deflection	0.042 in	Ratio =	4518 >=180
Max Upward Total Deflection	0.000 in	Ratio =	0 <180

Maximum Forces & Stresses for Load Combinations

Load Combination / Segment Length	Span #	Max Stress Ratios M	V	Summary of Moment Values Mmax +	Mmax -	Ma Max	Mnx	Mnx/Omega	Cb	Rm	Summary of Shear Values Va Max	Vnx	Vnx/Omega
+D+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+L+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+Lr+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+S+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.750Lr+0.750L+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.750L+0.750S+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.60W+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.70E+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.750Lr+0.750L+0.450W+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.750L+0.750S+0.450W+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+D+0.750L+0.750S+0.5250E+H													
Dsgn. L = 16.00 ft	1	0.039	0.011	1.65		1.65	70.83	42.42	1.00	1.00	0.43	56.17	37.44
+0.60D+0.60W+0.60H													

Project Name LPC - Upper System Tank
Project # 16194
Prepared By WWY
Date 8/23/2016

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

ENGINEERS
structural consultants

Circular Concrete Tanks without Prestressing

(Based on the 1993 PCA Document)

Design Criteria

f'c	4500	psi
D_{tank}	53	ft
H_{tank}	16	ft
t_{wall}	12	in
Fluid Pressure	62.4	pcf
Soil Pressure	104	pcf
E_s	29000000	psi
E_c	3823676.24	psi
n	7.6	
Surcharge	175	pcf
Soil on Lid	1	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	4.83	

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}	43647	lbs.
$T_{unfactored}$	16154	lbs.
$A_{s(req'd)}$	0.81	in^2
$A_{s(used)}$	0.88	in^2

OK

Compression Check	
F'c	684
0.33f'c	1485
OK	

$F_{t(conc)}$ 158 psi

This equates to 3.51 % 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= 71488.4352

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	-268	0	0
0.1H	0.118	8429	0.0000	12
0.2H	0.238	17018	0.0002	139
0.3H	0.358	25583	0.0008	532
0.4H	0.469	33528	0.0019	1304
0.5H	0.559	39970	0.0038	2618
0.6H	0.611	43647	0.0061	4241
0.7H	0.597	42679	0.0085	5865
0.8H	0.493	35279	0.0098	6773
0.9H	0.288	20556	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= 1 ft
p 175

Ring Force=(A-5 Coef.)w_uHR+(A-6 Coef.)pR
w_uHR= -136168
pR= -14320.6

Moment=(A-7 Coef.)($w_u h^3+ph^2$)
$w_u h^3+ph^2$= -1273000

	A-5 Coef	RF (#)	A-6 Coef.	RF (#)	Total RF (#)	A-7 Coef.	Moment (#-ft/ft)
Top	-0.004	511	0.996	-14266.8302	-13756	0	0
0.1H	0.118	-16055	1.018	-14577.0198	-30632	0.0000	-22
0.2H	0.238	-32416	1.038	-14865.5934	-47281	0.0002	-257
0.3H	0.358	-48730	1.058	-15149.3034	-63880	0.0008	-980
0.4H	0.469	-63863	1.069	-15308.7214	-79172	0.0019	-2404
0.5H	0.559	-76134	1.059	-15167.1366	-91301	0.0038	-4825
0.6H	0.611	-83137	1.011	-14471.6418	-97609	0.0061	-7818
0.7H	0.597	-81293	0.897	-12845.5782	-94138	0.0085	-10811
0.8H	0.493	-67198	0.693	-9931.201	-77129	0.0098	-12485
0.9H	0.288	-39155	0.388	-5549.908	-44705	0.0080	-10232
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) = -13756 #

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= -1029 #
VR/H= -1704 #

$Delta_{RF}$=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_{DM}/S_{DC})

$Delta_{mom}$=(A-9 Coef.)VH
VH= -16465

	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	13756	-13756	0	0	0	0	0
0.1H	-4.946	8430	-30632	-22202	0.0647	-1065	-22	-1087
0.2H	-2.475	4219	-47281	-43062	0.0797	-1312	-257	-1569
0.3H	-0.843	1436	-63880	-62443	0.0694	-1142	-980	-2122
0.4H	0.059	-101	-79172	-79272	0.0497	-819	-2404	-3223
0.5H	0.434	-740	-91301	-92041	0.0305	-503	-4825	-5328
0.6H	0.480	-817	-97609	-98426	0.0150	-248	-7818	-8066
0.7H	0.363	-619	-94138	-94757	0.0042	-69	-10811	-10880
0.8H	0.198	-338	-77129	-77467	-0.0027	44	-12485	-12441
0.9H	0.060	-102	-44705	-44807	-0.0075	124	-10232	-10108
Bottom	0.000	0	0	0	-0.0124	203	0	203

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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= -33 # (For Ring Force)
VH= -321 # (For Moment)

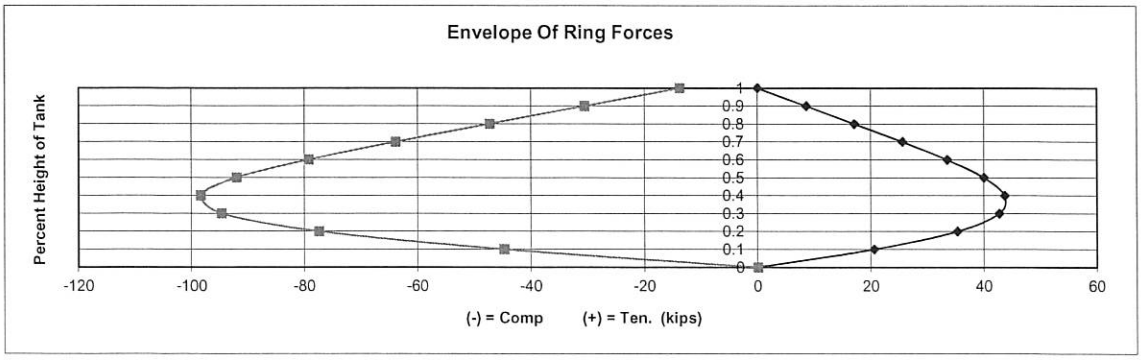
	A-8 Coef.	$Delta_{RF}$ (#)	LC#1 RF (#)	Total RF (#)	A-9 Coef.	$Delta_{mom}$ (#-ft/ft)	LC#1 Moment (#-ft/ft)	Total Moment (#-ft/ft)
Top	-8.07	268	-268	0	0	0	0	0
0.1H	-4.95	164	8429	8593	0.065	-21	12	-9
0.2H	-2.48	82	17018	17101	0.080	-26	139	114
0.3H	-0.84	28	25583	25611	0.069	-22	532	509
0.4H	0.06	-2	33528	33526	0.050	-16	1304	1288
0.5H	0.43	-14	39970	39956	0.031	-10	2618	2608
0.6H	0.48	-16	43647	43631	0.015	-5	4241	4237
0.7H	0.36	-12	42679	42667	0.004	-1	5865	5864
0.8H	0.20	-7	35279	35272	-0.003	1	6773	6774
0.9H	0.06	-2	20556	20554	-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	-268	-13756	0	0	0	-13756
0.1H	8429	-30632	-22202	8593	8593	-30632
0.2H	17018	-47281	-43062	17101	17101	-47281
0.3H	25583	-63880	-62443	25611	25611	-63880
0.4H	33528	-79172	-79272	33526	33528	-79272
0.5H	39970	-91301	-92041	39956	39970	-92041
0.6H	43647	-97609	-98426	43631	43647	-98426
0.7H	42679	-94138	-94757	42667	42679	-94757
0.8H	35279	-77129	-77467	35272	35279	-77467
0.9H	20556	-44705	-44807	20554	20556	-44807
Bottom	0	0	0	0	0	0

	Tension	Compression
Bottom	0	0
0.9H	21	-45
0.8H	35	-77
0.7H	43	-95
0.6H	44	-98
0.5H	40	-92
0.4H	34	-79
0.3H	26	-64
0.2H	17	-47
0.1H	9	-31
Top	0	-14

Controls



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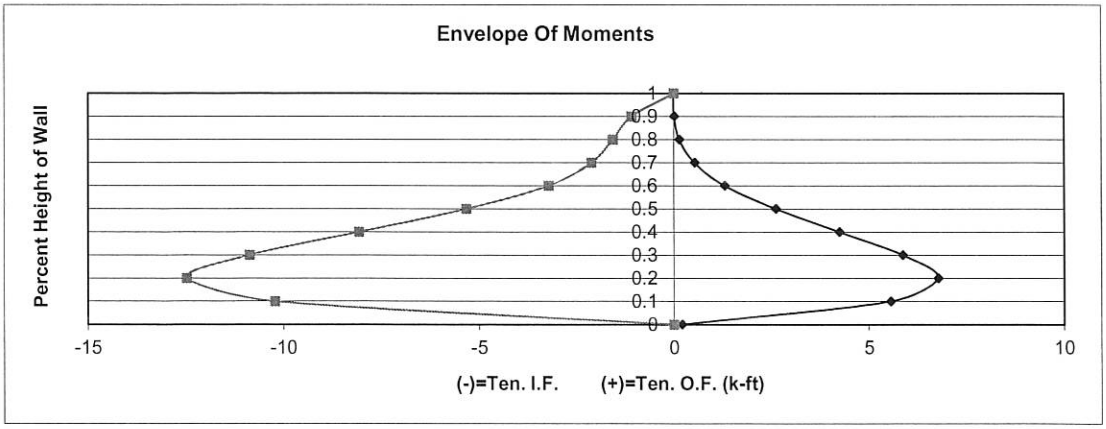
Envelope of Moments

	LC#1	LC#2	LC#3	LC#4	Max	Min
Top	0	0	0	0	0	0
0.1H	12	-22	-1087	-9	12	-1087
0.2H	139	-257	-1569	114	139	-1569
0.3H	532	-980	-2122	509	532	-2122
0.4H	1304	-2404	-3223	1288	1304	-3223
0.5H	2618	-4825	-5328	2608	2618	-5328
0.6H	4241	-7818	-8066	4237	4241	-8066
0.7H	5865	-10811	-10880	5864	5865	-10880
0.8H	6773	-12485	-12441	6774	6774	-12485
0.9H	5551	-10232	-10108	5553	5553	-10232
Bottom	0	0	203	4	203	0

	Tension O.F.	Tension I.F.
Bottom	0	0
0.9H	6	-10
0.8H	7	-12 ← Controls
0.7H	6	-11
0.6H	4	-8
0.5H	3	-5
0.4H	1	-3
0.3H	1	-2
0.2H	0	-2
0.1H	0	-1
Top	0	0



Design of Wall Steel

Ring steel

- Compression

$$f_c = C/A = 98^k/12 \cdot 12 = 681 \text{ psi}$$

$C = 98^k$ @ $0.6H$

$1/3\,(4500 \text{ psi}) = 1500 \text{ psi} > 681 \text{ psi} \therefore \text{OK}$

- Tension

$$A_s = 44.0^k/0.9 \cdot 60 \text{ KSI} = 0.82 \text{ in}^2$$

USE #6 BARS @ 12" o.c. Each Face = $0.88 \text{ in}^2 > 0.82 \text{ in}^2 \therefore$ OK

F_t OK (see spreadsheet)

Design of Wall Steel

Moment Reinforcing

- steel at Interior Face

$m_u = 12$ k-ft

$$\frac{m_u}{\phi f'_c b d^2} = \frac{12\text{k-ft} \cdot 12}{0.9 \cdot 4.5 \cdot 12'' \cdot 9.5^2} = 0.0328$$

$W = 0.034$ [Table A-20]

$\rho = 0.034 \cdot 4.5/60 = 0.00255$

ρ_{min} (temp. shrinkage) $= 0.003$

∴ MIN Reinforcemnt provided is adequate

* $m_u = 7$ k-ft @ Exterior Face ∴ min. steel Reinforcement is adequate