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ENGINEERS

structural consultants

Structural Calculations

For

OSPREY RANCH WATER TANK

Project Number: 21498

February 9, 2022



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

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ENGINEERS

structural consultants

STRUCTURAL CALCULATIONS

FOR

OSPREY RANCH WATER TANK

Client: Great Basin Engineering, Inc.

Project Number: 21498

DESIGN CRITERIA

GOVERNING CODE: IBC 2018

GENERAL: Risk Category = IV

SEISMIC: Seismic Design Category = D

$I_E = 1.5$

$S_{DS} = 0.810$

$S_{D1} = 0.364$

SOILS: Site Class: C

Design Allowable Soil Bearing Pressure = 3000 psf

Soils report by: Christensen Geotechnical

Report Number: 133-014

Dated: January 7, 2021

DESIGN CRITERIASNOW LOAD $\rightarrow P_g = \underline{86}$ PSF

* NO SOIL ON LID

SOIL CRITERIA

AT REST PRESSURE = 57 PCFPASSIVE PRESSURE = 424 PCFFRICTION = 0.4SEISMIC AT-REST PRESSURE = $57 + 24$ PCF = 81 PCFSEISMIC PASSIVE PRESSURE = -55 PCFSEISMIC CRITERIA :

$$S_s = 1.013$$

$$S_1 = 0.364$$

$$S_{MS} = 1.215$$

$$S_{M1} = 0.546$$

$$S_{DS} = 0.810$$

$$S_{D1} = 0.364$$

SITE CLASS C

NOTE: ALL VALUES ARE BASED ON THE 2018 IBC.

ATC Hazards by Location

Search Information

Address: 137 W 17th St, Ogden, UT 84404, USA

Coordinates: 41.29328, -111.84988

Elevation: 5705 ft

Timestamp: 2022-01-26T00:51:27.088Z

Hazard Type: Seismic

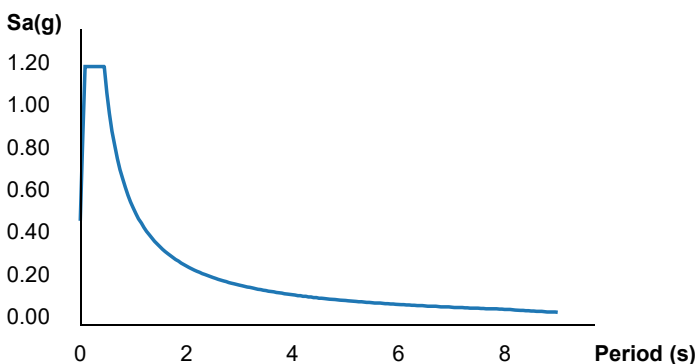
Reference Document: ASCE7-16

Risk Category: IV

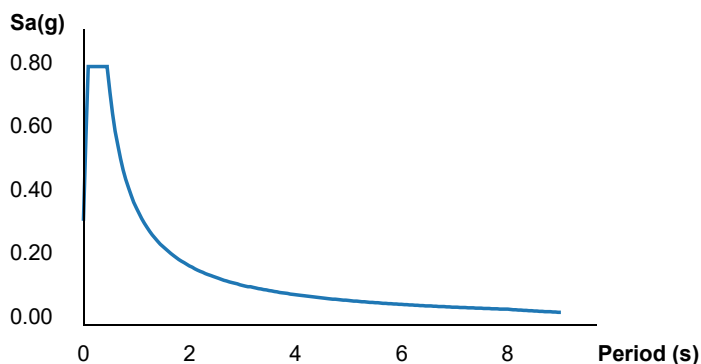
Site Class: C



MCER Horizontal Response Spectrum



Design Horizontal Response Spectrum



Basic Parameters

| Name | Value | Description |
|-----------------|-------|--|
| S _S | 1.013 | MCE _R ground motion (period=0.2s) |
| S ₁ | 0.364 | MCE _R ground motion (period=1.0s) |
| S _{MS} | 1.215 | Site-modified spectral acceleration value |
| S _{M1} | 0.546 | Site-modified spectral acceleration value |
| S _{DS} | 0.81 | Numeric seismic design value at 0.2s SA |
| S _{D1} | 0.364 | Numeric seismic design value at 1.0s SA |

Additional Information

| Name | Value | Description |
|-----------------|-------|-----------------------------------|
| SDC | D | Seismic design category |
| F _a | 1.2 | Site amplification factor at 0.2s |
| F _v | 1.5 | Site amplification factor at 1.0s |
| CR _S | 0.874 | Coefficient of risk (0.2s) |

| | | |
|------------------|-------|--|
| CR ₁ | 0.871 | Coefficient of risk (1.0s) |
| PGA | 0.45 | MCE _G peak ground acceleration |
| F _{PGA} | 1.2 | Site amplification factor at PGA |
| PGA _M | 0.54 | Site modified peak ground acceleration |
| T _L | 8 | Long-period transition period (s) |
| SsRT | 1.013 | Probabilistic risk-targeted ground motion (0.2s) |
| SsUH | 1.158 | Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years) |
| SsD | 1.623 | Factored deterministic acceleration value (0.2s) |
| S1RT | 0.364 | Probabilistic risk-targeted ground motion (1.0s) |
| S1UH | 0.418 | Factored uniform-hazard spectral acceleration (2% probability of exceedance in 50 years) |
| S1D | 0.682 | Factored deterministic acceleration value (1.0s) |
| PGAd | 0.633 | Factored deterministic acceleration value (PGA) |

The results indicated here DO NOT reflect any state or local amendments to the values or any delineation lines made during the building code adoption process. Users should confirm any output obtained from this tool with the local Authority Having Jurisdiction before proceeding with design.

Disclaimer

Hazard loads are provided by the U.S. Geological Survey [Seismic Design Web Services](#).

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Utah Ground Snow Load Map

Osprey Ranch Water Tank



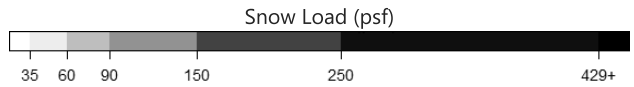
Latitude: 41.293

Longitude: -111.850

Elevation: 5,779 ft

Ground Snow Load:

86 psf / 4.12 kPa



*This document is not legally binding. The user is urged to verify ground snow load values with the local authority having jurisdiction.

These ground snow load values represent 50-year ground snow load estimated value at a 2% probability of exceedance for the location given. The grid used in the map is 3350ft by 3350ft. Elevations for these grid cells were estimated by aggregating data from 100ft by 100ft USGS digital elevation models and may not coincide with the actual site elevation. These predictions are calculated using the process outlined in The Utah Snow Load Study.¹

Final predictions given are bounded at a lower limit for a minimum ground snow load of 21 psf to meet ASCE 7. Estimated values for snow loads at elevations significantly higher than all nearby stations lead to unreasonably high snow load estimates, therefore, the predictions in the map are not allowed to extend beyond the highest 50-year station ground snow load of 429 psf. Elevations over 9,000 ft are also considered less accurate due to the limited number of stations at these elevations. The results shown in this report have included a warning if the results have reached or exceeded the upper limit.

While great efforts have been made to ensure these predictions are as accurate as possible, designers must use expert judgement to ensure that such predictions are appropriate for their particular project. The SEAU and the authors cannot accept responsibility for prediction errors or any consequences resulting therefrom.

¹ Bean, Brennan; Maguire, Marc; and Sun, Yan, "The Utah Snow Load Study" (2018). Civil and Environmental Engineering Faculty Publications. Paper 3589.

ENVIRONMENTAL FACTORS :

WATER COMBINATIONS : $\gamma = 1.4$

$$S_d = \frac{0.9 (60000)}{1.4 (29000)} = 1.93$$

SOIL COMBINATIONS : $\gamma = 1.6$

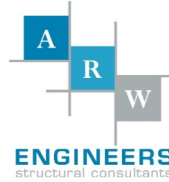
$$S_d = \frac{0.9 (60000)}{1.6 (29000)} = 1.69$$

$$f_s = 20000 \text{ PSI (CONSERVATIVE)}$$

$$\therefore S_d = 1.93$$

Project Name Osprey Ranch Water Tank
Project # 21498
Prepared By MOW
Date 2/8/2022

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



Circular Concrete Tanks without Prestressing
(Based on the 1993 PCA Document)

Design Criteria

| | | |
|------------------------------|------------|-----|
| f _c | 4500 | psi |
| D _{tank} | 70 | ft |
| H _{tank} | 10.33 | ft |
| t _{wall} | 12 | in |
| Fluid Pressure | 62.4 | pcf |
| Soil Pressure | 103 | pcf |
| E _s | 29000000 | psi |
| E _c | 3823676.24 | psi |
| n | 7.6 | |
| Surcharge | 100 | 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 | 1.52 | |

Estimation of Tank Wall Thickness

Limit Ring Tension Stress in Concrete Wall from 7% to 12% of f_c

For given t and H²/Dt, with a hinged base/free top (Table A-5)

Max Coefficient= 0.380 (Table A-5)

W_u 169 pcf

T_{max} 23158 lbs.

T_{unfactored} 8571 lbs.

A_{s(req'd)} 0.43 in²

A_{s(used)} 0.62 in²
OK

| Compression Check | |
|--------------------------|------|
| F _c | 377 |
| 0.33f _c | 1485 |
| OK | |

F_{t(conc)} 94 psi

This equates to 2.09 % 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_lHR w_lHR= 60959.06544

Moment =(A-7 Coef.)w_lH³ w_lH³= 185853.5662

| | A-5 Coef. | RF (#) | A-7 Coef. | Moment (#-ft/ft) |
|--------|-----------|-----------|-----------|---------------------|
| Top | 0.286 | 17430 | 0 | 0 |
| 0.1H | 0.313 | 19070 | 0.0013 | 237 |
| 0.2H | 0.345 | 21017 | 0.0047 | 867 |
| 0.3H | 0.368 | 22413 | 0.0095 | 1762 |
| 0.4H | 0.380 | 23158 | 0.0151 | 2807 |
| 0.5H | 0.377 | 22985 | 0.0203 | 3772 |
| 0.6H | 0.352 | 21457 | 0.0244 | 4541 |
| 0.7H | 0.303 | 18473 | 0.0263 | 4883 |
| 0.8H | 0.224 | 13662 | 0.0238 | 4421 |
| 0.9H | 0.119 | 7259 | 0.0158 | 2937 |
| Bottom | 0.000 | 0 | 0 | 0 |

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 Reviewed By: TMD



Load Case #2-Empty, w/ Lid, w/ Backfill

Use Durability Coefficients as Noted Previous

Soil Over Lid= 1 ft
 p 100

Ring Force=(A-5 Coef.) w_u HR+(A-6 Coef.)pR Moment=(A-7 Coef.)(w_u h³+ph²)
 w_u HR= -114996 w_u h³+ph²= -335859
 pR= -10808

| | A-5 Coef | RF (#) | A-6 Coef. | RF (#) | Total RF (#) | A-7 Coef. | Moment (#-ft/ft) |
|--------|----------|--------|-----------|--------------|--------------|-----------|------------------|
| Top | 0.286 | -32881 | 1.286 | -13898.3148 | -46779 | 0 | 0 |
| 0.1H | 0.313 | -35974 | 1.213 | -13108.22696 | -49082 | 0.0013 | -428 |
| 0.2H | 0.345 | -39648 | 1.145 | -12372.77529 | -52021 | 0.0047 | -1567 |
| 0.3H | 0.368 | -42281 | 1.068 | -11539.45545 | -53821 | 0.0095 | -3183 |
| 0.4H | 0.380 | -43687 | 0.980 | -10590.73616 | -54277 | 0.0151 | -5073 |
| 0.5H | 0.377 | -43361 | 0.877 | -9479.300687 | -52840 | 0.0203 | -6816 |
| 0.6H | 0.352 | -40477 | 0.747 | -8074.856864 | -48552 | 0.0244 | -8206 |
| 0.7H | 0.303 | -34848 | 0.603 | -6517.654853 | -41366 | 0.0263 | -8825 |
| 0.8H | 0.224 | -25773 | 0.424 | -4583.872864 | -30357 | 0.0238 | -7989 |
| 0.9H | 0.119 | -13695 | 0.219 | -2367.89052 | -16062 | 0.0158 | -5307 |
| Bottom | 0.000 | 0 | 0.000 | 0 | 0 | 0 | 0 |

Load Case #3-Empty, No 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) = -46779 #

At top of wall (0.0H) from table A-8, Coefficient= -4.45 #

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= -3101 #
 VR/H= -10505 #

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.

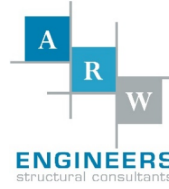
If S_D for moment is less than S_D for compression, then V is reduced by (S_{DM}/S_{DC})

Delta_{mom}=(A-9 Coef.)(VH)
 VH= -32029

| | 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 | -4.453 | 46779 | -46779 | 0 | 0 | 0 | 0 | 0 |
| 0.1H | -3.470 | 36455 | -49082 | -12627 | 0.0796 | -2548 | -428 | -2977 |
| 0.2H | -2.570 | 26996 | -52021 | -25025 | 0.1239 | -3968 | -1567 | -5535 |
| 0.3H | -1.798 | 18890 | -53821 | -34931 | 0.1424 | -4561 | -3183 | -7744 |
| 0.4H | -1.185 | 12450 | -54277 | -41827 | 0.1429 | -4577 | -5073 | -9650 |
| 0.5H | -0.713 | 7487 | -52840 | -45353 | 0.1314 | -4209 | -6816 | -11025 |
| 0.6H | -0.383 | 4020 | -48552 | -44532 | 0.1126 | -3605 | -8206 | -11811 |
| 0.7H | -0.177 | 1860 | -41366 | -39507 | 0.0897 | -2873 | -8825 | -11697 |
| 0.8H | -0.059 | 625 | -30357 | -29732 | 0.0654 | -2096 | -7989 | -10085 |
| 0.9H | -0.012 | 125 | -16062 | -15937 | 0.0402 | -1288 | -5307 | -6595 |
| Bottom | 0.000 | 0 | 0 | 0 | 0.0150 | -479 | 0 | -479 |

Project Name Osprey Ranch Water Tank
 Project # 21498
 Prepared By MOW
 Date 2/8/2022

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



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= -4.45 #

(Coef. A-8 @ 0.0H)(VR/H) = (Ring Force from LC#1)

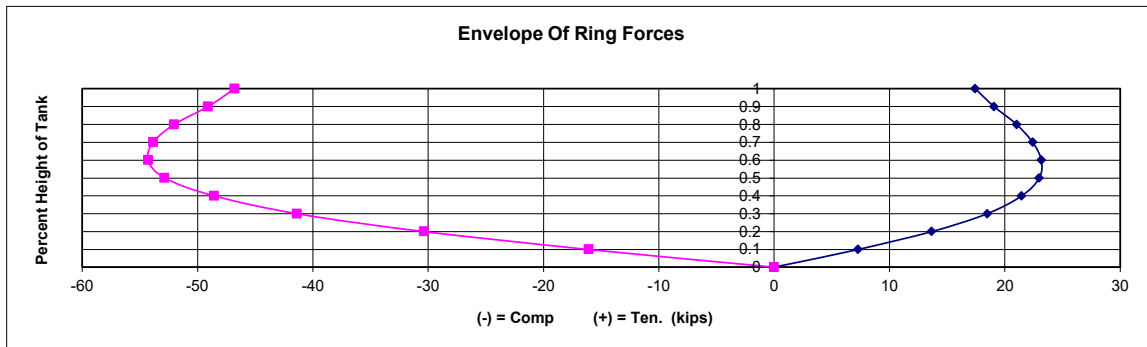
V= 1155 #
 VR/H= 3914 # (For Ring Force)
 VH= 11934 # (For Moment)

| | 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 | -4.45 | -17430 | 17430 | 0 | 0 | 0 | 0 | 0 |
| 0.1H | -3.47 | -13583 | 19070 | 5487 | 0.080 | 950 | 237 | 1187 |
| 0.2H | -2.57 | -10059 | 21017 | 10958 | 0.124 | 1479 | 867 | 2345 |
| 0.3H | -1.80 | -7038 | 22413 | 15375 | 0.142 | 1699 | 1762 | 3461 |
| 0.4H | -1.19 | -4639 | 23158 | 18519 | 0.143 | 1706 | 2807 | 4513 |
| 0.5H | -0.71 | -2790 | 22985 | 20196 | 0.131 | 1568 | 3772 | 5340 |
| 0.6H | -0.38 | -1498 | 21457 | 19959 | 0.113 | 1343 | 4541 | 5884 |
| 0.7H | -0.18 | -693 | 18473 | 17780 | 0.090 | 1070 | 4883 | 5954 |
| 0.8H | -0.06 | -233 | 13662 | 13429 | 0.065 | 781 | 4421 | 5202 |
| 0.9H | -0.01 | -47 | 7259 | 7213 | 0.040 | 480 | 2937 | 3417 |
| Bottom | 0 | 0 | 0 | 0 | 0.015 | 179 | 0 | 179 |

Envelope of Ring Forces

| | LC#1 | LC#2 | LC#3 | LC#4 | Max | Min |
|--------|-------|--------|--------|-------|-------|--------|
| Top | 17430 | -46779 | 0 | 0 | 17430 | -46779 |
| 0.1H | 19070 | -49082 | -12627 | 5487 | 19070 | -49082 |
| 0.2H | 21017 | -52021 | -25025 | 10958 | 21017 | -52021 |
| 0.3H | 22413 | -53821 | -34931 | 15375 | 22413 | -53821 |
| 0.4H | 23158 | -54277 | -41827 | 18519 | 23158 | -54277 |
| 0.5H | 22985 | -52840 | -45353 | 20196 | 22985 | -52840 |
| 0.6H | 21457 | -48552 | -44532 | 19959 | 21457 | -48552 |
| 0.7H | 18473 | -41366 | -39507 | 17780 | 18473 | -41366 |
| 0.8H | 13662 | -30357 | -29732 | 13429 | 13662 | -30357 |
| 0.9H | 7259 | -16062 | -15937 | 7213 | 7259 | -16062 |
| Bottom | 0 | 0 | 0 | 0 | 0 | 0 |

| | Tension | Compression |
|--------|---------|-------------|
| Bottom | 0 | 0 |
| 0.9H | 7 | -16 |
| 0.8H | 14 | -30 |
| 0.7H | 18 | -41 |
| 0.6H | 21 | -49 |
| 0.5H | 23 | -53 |
| 0.4H | 23 | -54 |
| 0.3H | 22 | -54 |
| 0.2H | 21 | -52 |
| 0.1H | 19 | -49 |
| Top | 17 | -47 |



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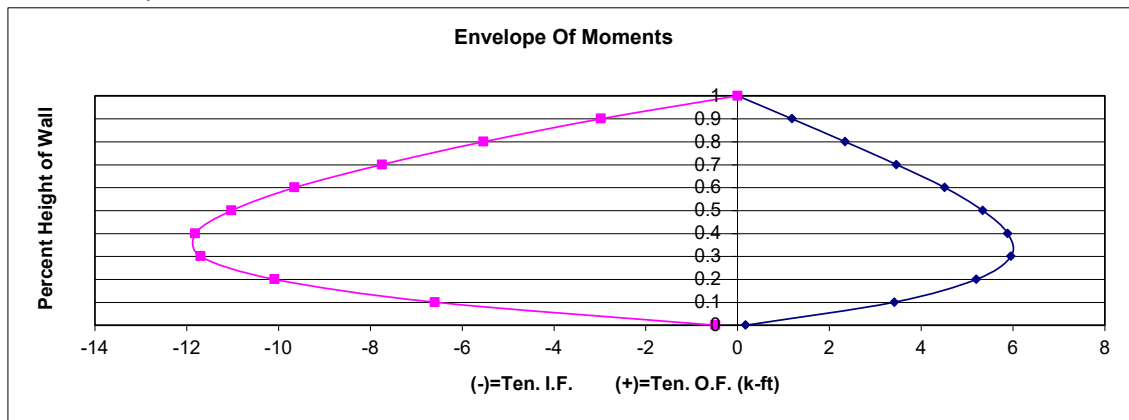
Program Authors: TAB & DOC
 Last Revised 1/19/2006
 Reviewed By: TMD



Envelope of Moments

| | LC#1 | LC#2 | LC#3 | LC#4 | Max | Min |
|--------|------|-------|--------|------|------|--------|
| Top | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.1H | 237 | -428 | -2977 | 1187 | 1187 | -2977 |
| 0.2H | 867 | -1567 | -5535 | 2345 | 2345 | -5535 |
| 0.3H | 1762 | -3183 | -7744 | 3461 | 3461 | -7744 |
| 0.4H | 2807 | -5073 | -9650 | 4513 | 4513 | -9650 |
| 0.5H | 3772 | -6816 | -11025 | 5340 | 5340 | -11025 |
| 0.6H | 4541 | -8206 | -11811 | 5884 | 5884 | -11811 |
| 0.7H | 4883 | -8825 | -11697 | 5954 | 5954 | -11697 |
| 0.8H | 4421 | -7989 | -10085 | 5202 | 5202 | -10085 |
| 0.9H | 2937 | -5307 | -6595 | 3417 | 3417 | -6595 |
| Bottom | 0 | 0 | -479 | 179 | 179 | -479 |

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





ENGINEERS

Project No. 21498 Sheet No.

Project OSPREY RANCH WATER TANK

Prepared By NOW Date 2/8/2022

WALL DESIGN

SEE SPREADSHEET FOR MAX TENSION AND COMPRESSION CHECK

RING STEEL (HORIZONTAL BARS)

MAX RING FORCE = 23.2 k

As req = 23.2 / (0.9 * 60) = 0.43 in^2

(2) #5 GIVES 0.62 > 0.43 ok.

CHECK MIN SHRINKAGE STEEL

As min = 0.005 (12") (12") = 0.72 in^2/ft

#6 BARS AT 12" O.C. GIVES 0.88 in^2/ft

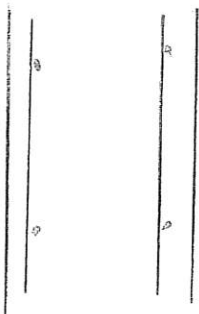
MOMENT REINF - VERT BARS

MAX MOMENT

TENSION INSIDE FACE 12 k-ft/ft

TENSION OUTSIDE FACE 6 k-ft/ft

INSIDE



12"

12" O.C.

f'c = 4,500 PSI

d = 9.5" INSIDE, 8.5" OUTSIDE

b = 12"

TEMP STEEL = 0.003

0.003 * 12 * 12 = 0.432 in^2/ft BOTH FACES

FLEXURE As req

As min = 3 * sqrt(4500) / 10,000 * 12 * 9.5 = 0.382 in^2 ONE FACE

USE #6 @ 12" O.C. EA FACE.

INSIDE FACE

phi Mn = 17.96 k-ft/ft

OUTSIDE FACE

phi Mn = 15.98 k-ft/ft

MINIMUM STEEL CONTROLS.



ENGINEERS

Project No. 21498 Sheet No. _____
Project OSPREY RANCH WATER TANK
Prepared By MOW Date 2/8/2022

WALL DESIGN (CONT'D)

SHEAR STRENGTH OF WALL

WALL CAPACITY $\phi V_c = 0.75(2) \sqrt{4500} (12 \text{ in}) \times 0.5 \text{ in} = 10,263 \#$
10.26k

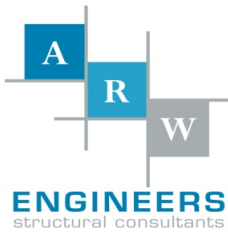
V_{MAX} IN WALL

$H^2/D+ = 1.52$

COEFF = 0.207 (TABLE A-12)

$V = 0.207 (110 \text{ PCF}) (10.33^2) 1.6 = 3889 \#$
 $3.9k < 10.26k$

∴ OK.



Concrete Water Tank - Roof Design

2/8/2022
4:57:52 PM

Version Date: 12/16/20

Author: TAB

Job Title: Osprey Ranch Water Tank

Job #: 21498

Engineer: MOW

Roof Slab Design

Min Thickness

| | | | |
|--------------------|-------------------|-----------------------|-----------|
| Slab Span | 17.5 ft | Est. Column Thickness | 16 in |
| | h_{min} 5.88 in | | |
| Use Slab Thickness | 8 in | d | 5.0625 in |
| f_c | 4500 psi | f_y | 60 ksi |

Loads

| | |
|-----------|-----------|
| Dead Load | 115 psf |
| Live Load | 20 psf |
| Soil Load | 0 psf |
| Snow Load | 86 psf |
| W_U | 295.6 psf |

Shear Capacity of Slab

| | | |
|----------------------------|---------------------|---|
| Round Column Dim | 16 in | |
| | b_o 66.1698 in | |
| | V_U 90.5275 kips | |
| ϕV_C (No Drop Panel) | 67.4143 kips | NG Use Drop Panel |
| Drop Panel Dimension | 6 ft square | Wide enough to reduce negative moment reinforcing |
| | New b_o 308.25 in | |
| ϕV_C Drop Panel | 314.048 kips | Ok |
| Drop Panel Thickness | 4 in | |
| | b_o 80.1106 in | |
| ϕV_C | 153.159 kips | Ok |

Flexural Design by Direct Design Method Of ACI 318

| | | | |
|----------------------------|--------------|--------------------------------|-------------|
| l_2 | 17.5 ft | S_d | 1.93 |
| l_n | 16.1667 ft | Strip Width | 8.75 ft |
| M_o | 169.003 K-ft | | |
| Exterior Span M^+ factor | 0.63 | Exterior M^+ factored Moment | 106.47 k-ft |
| Exterior Span M^- factor | 0.75 | Exterior M^- factored Moment | 126.75 k-ft |
| Interior Span M^+ factor | 0.35 | Interior M^+ factored Moment | 59.151 k-ft |
| Interior Span M^- factor | 0.65 | Interior M^- factored Moment | 109.85 k-ft |

Col Strip Factored Mom.

| | |
|----------------|------|
| M^+ | 0.6 |
| Exterior M^- | 1 |
| Interior M^- | 0.75 |

Mid Strip Factored Mom

| | |
|--|------|
| | 0.4 |
| | 0.25 |
| | 0.25 |

Exterior Positive Moment

| | | | |
|--------------------------|-------------------------|--------------------------|-----------------------|
| Column Strip | 123.294 k-ft | Middle Strip | 82.196 k-ft |
| Moment per foot of width | 14.0908 k-ft/ft | Moment per foot of width | 9.3938 k-ft/ft |
| Mu/ϕ | 15.6564 k-ft/ft | Mu/ϕ | 10.438 k-ft/ft |
| Mu/ϕ | 187.877 k-in/ft | Mu/ϕ | 125.25 k-in/ft |
| As | 0.67785 in ² | As | 0.437 in ² |
| a | 0.88607 | a | 0.5712 |
| #4 Bar Spacing | 3.54 in oc | #4 Bar Spacing | 5.49 in oc |
| #5 Bar Spacing | 5.49 in oc | #5 Bar Spacing | 8.51 in oc |
| #6 Bar Spacing | 7.79 in oc | #6 Bar Spacing | 12.08 in oc |
| #7 Bar Spacing | 10.62 in oc | #7 Bar Spacing | 16.48 in oc |
| #8 Bar Spacing | 13.99 in oc | #8 Bar Spacing | 21.69 in oc |

Exterior Negative Moment

| | | | |
|--------------------------|------------------------|--------------------------|----------------------|
| d | 5.0625 in | Middle Strip | 61.158 k-ft |
| Column Strip | 244.631 k-ft | Moment per foot of width | 6.9895 k-ft/ft |
| Moment per foot of width | 27.9579 k-ft/ft | Mu/ϕ | 7.7661 k-ft/ft |
| Mu/ϕ | 31.0643 k-ft/ft | Mu/ϕ | 93.193 k-in/ft |
| Mu/ϕ | 372.772 k-in/ft | As | 0.32 in ² |
| As | 1.5291 in ² | a | 0.4183 |
| a | 1.99882 | #4 Bar Spacing | 7.50 in oc |
| #4 Bar Spacing | 1.57 in oc | #5 Bar Spacing | 11.62 in oc |
| #5 Bar Spacing | 2.43 in oc | #6 Bar Spacing | 16.50 in oc |
| #6 Bar Spacing | 3.45 in oc | #7 Bar Spacing | 22.50 in oc |
| #7 Bar Spacing | 4.71 in oc | #8 Bar Spacing | 29.62 in oc |
| #8 Bar Spacing | 6.20 in oc | | |

Reduced column strip negative reinforcement if drop panel is wide enough to increase d
 Increased d 9.0625 in extend drop panel L/6 past column each side to increase d

| | |
|--------------------------|-------------------------|
| Column Strip | 244.631 k-ft |
| Moment per foot of width | 27.9579 k-ft/ft |
| Mu/ϕ | 31.0643 k-ft/ft |
| Mu/ϕ | 372.772 k-in/ft |
| As | 0.74373 in ² |
| a | 1.41779 |
| #4 Bar Spacing | 3.23 in oc |
| #5 Bar Spacing | 5.00 in oc |
| #6 Bar Spacing | 7.10 in oc |
| #7 Bar Spacing | 9.68 in oc |
| #8 Bar Spacing | 12.75 in oc |

Interior Positive Moment

| | | | |
|--------------------------|-------------------------|--------------------------|------------------------|
| Column Strip | 68.4968 k-ft | Middle Strip | 45.665 k-ft |
| Moment per foot of width | 7.8282 k-ft/ft | Moment per foot of width | 5.2188 k-ft/ft |
| Mu/φ | 8.698 k-ft/ft | Mu/φ | 5.7987 k-ft/ft |
| Mu/φ | 104.376 k-in/ft | Mu/φ | 69.584 k-in/ft |
| As | 0.36039 in ² | As | 0.2363 in ² |
| a | 0.4711 | a | 0.3089 |
| #4 Bar Spacing | 6.66 in oc | #4 Bar Spacing | 10.16 in oc |
| #5 Bar Spacing | 10.32 in oc | #5 Bar Spacing | 15.74 in oc |
| #6 Bar Spacing | 14.65 in oc | #6 Bar Spacing | 22.35 in oc |
| #7 Bar Spacing | 19.98 in oc | #7 Bar Spacing | 30.47 in oc |
| #8 Bar Spacing | 26.30 in oc | #8 Bar Spacing | 40.12 in oc |

Interior Negative Moment

| | | | |
|--------------------------|-------------------------|--------------------------|------------------------|
| d | 5.0625 in | Middle Strip | 53.003 k-ft |
| Column Strip | 159.01 k-ft | Moment per foot of width | 6.0575 k-ft/ft |
| Moment per foot of width | 18.1726 k-ft/ft | Mu/φ | 6.7306 k-ft/ft |
| Mu/φ | 20.1918 k-ft/ft | Mu/φ | 80.767 k-in/ft |
| Mu/φ | 242.301 k-in/ft | As | 0.2757 in ² |
| As | 0.90297 in ² | a | 0.3604 |
| a | 1.18035 | #4 Bar Spacing | 8.70 in oc |
| #4 Bar Spacing | 2.66 in oc | #5 Bar Spacing | 13.49 in oc |
| #5 Bar Spacing | 4.12 in oc | #6 Bar Spacing | 19.15 in oc |
| #6 Bar Spacing | 5.85 in oc | #7 Bar Spacing | 26.11 in oc |
| #7 Bar Spacing | 7.97 in oc | #8 Bar Spacing | 34.38 in oc |
| #8 Bar Spacing | 10.50 in oc | | |

Reduced column strip negative reinforcement if drop panel is wide enough to increase d

| | | |
|--------------------------|-------------------------|---|
| Increased d | 9.0625 in | extend drop panel L/6 past column each side to increase d |
| Column Strip | 159.01 k-ft | |
| Moment per foot of width | 18.1726 k-ft/ft | |
| Mu/φ | 20.1918 k-ft/ft | |
| Mu/φ | 242.301 k-in/ft | |
| As | 0.46872 in ² | |
| a | 0.89353 | |
| #4 Bar Spacing | 5.12 in oc | |
| #5 Bar Spacing | 7.94 in oc | |
| #6 Bar Spacing | 11.26 in oc | |
| #7 Bar Spacing | 15.36 in oc | |
| #8 Bar Spacing | 20.23 in oc | |

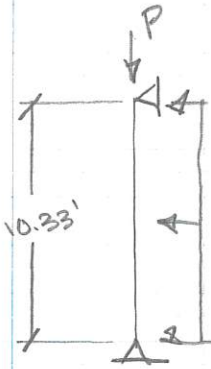
How Far past support must negative moment reinf. Extend?

| | | | |
|--------------|------------|-----|--------|
| Column Strip | 5.335 ft | Use | 5.5 ft |
| Middle Strip | 3.55667 ft | Use | 4 ft |

COLUMN DESIGN:

$$DL = 115 \text{ PSF} (17.5)^2 (1.32) (1 + 0.2 (0.810)) = 54 \text{ K}$$

$$SL = 86 \text{ PSF} (17.5)^2 (1.32) = 34.8 \text{ K}$$



$$H = 62.4 \times 1.5 \times \frac{16}{2} + 0.4 (0.810) (1.25) \frac{\pi \left(\frac{16}{2}\right)^2}{4} \times 150 \text{ PCF}$$

$$= 210 \text{ PLF}$$

∴ USE 16" Ø COLUMN W/ (8) #5 VERT.

TRANSVERSE REINFORCEMENT → ACI 350 21.4.4

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

$$\text{SPACING} = 16/4 = 4"$$

$$6 \frac{5}{8} = 3.75"$$

PER ACI 318 25.7.3.3

$$\rho_s \rightarrow A_g = \pi (16^2) / 4 = 201 \text{ in}^2$$

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

$$\rho_s = 0.45 \left(\frac{201}{113} - 1 \right) \frac{4.5}{60} = 0.026 \quad \text{CONTROLS}$$

REQ'D PITCH #4 TIES

$$0.026 = \frac{0.2 \pi (12.5)}{113 \times s}, \quad s \leq 2.7"$$

∴ USE 2.5"

REQ'D SPACING OF #3 HOOPS

$$0.009 = \frac{0.11 \pi (12.625)}{113 \times s}, \quad s \leq 4.3$$

∴ USE #4 SPIRAL TIES @ 2.5" PITCH
OR #3 HOOPS @ 3" O.C.

FOOTINGSCOLUMN FOOTING :

$$\left. \begin{array}{l} DL = 54^k \\ SL = 34.8^k \end{array} \right\}$$

$$\frac{88.8}{3 \text{ ksf}} = \sqrt{29.6} = 5.44'$$

\therefore USE 6' MIN

WALL FOOTING :

$$DL = 115 \text{ PSF } (18.5/2) = 1064 \text{ PLF}$$

$$SL = 86 \text{ PSF } (18.5/2) = 796 \text{ PLF}$$

$$\text{WALL DL} = \frac{12}{12} \times 150 \times 10.33' = 1550 \text{ PLF}$$

3410 PLF

\therefore USE FC3

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

Project Title:
 Engineer:
 Project ID:
 Project Descr:

Printed: 8 FEB 2022, 5:40PM

Concrete Column

File: 21498 Osprey Ranch Water Tank.ec6
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ARW ENGINEERS

Lic. #: KW-06002489

DESCRIPTION: Columns

Code References

Calculations per ACI 318-14, IBC 2018, CBC 2019, ASCE 7-16
 Load Combinations Used : IBC 2018

General Information

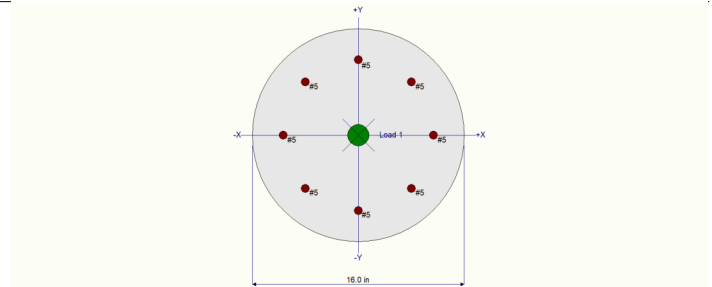
f'_c : Concrete 28 day strength = 4.50 ksi
 E = 3,823.68 ksi
 Density = 150.0 pcf
 β = 0.8250
 f_y - Main Rebar = 60.0 ksi
 E - Main Rebar = 29,000.0 ksi
 Allow. Reinforcing Limits *ASTM A615 Bars Used*
 Min. Reinf. = 1.0 %
 Max. Reinf. = 8.0 %

Overall Column Height = 10.330 ft
 End Fixity **Top & Bottom Pinned**
 Brace condition for deflection (buckling) along columns :
 X-X (width) axis :
 Unbraced Length for buckling ABOUT Y-Y Axis = 10.330 ft, $K = 1.0$
 Y-Y (depth) axis :
 Unbraced Length for buckling ABOUT X-X Axis = 10.330 ft, $K = 1.0$

Column Cross Section

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

Column Reinforcing : 8 - #5 bars



Entered loads are factored per load combinations specified by user.

Applied Loads

Column self weight included : 2,163.51 lbs * Dead Load Factor

AXIAL LOADS . . .

Axial Load at 10.330 ft above base, $D = 54.0$, $S = 34.80$ k

BENDING LOADS . . .

Lat. Uniform Load creating M_{x-x} , $H = 0.210$ k/ft

DESIGN SUMMARY

Load Combination **+1.20D+1.60S+1.60H**
 Location of max. above base **10.261** ft
Maximum Stress Ratio 0.260 : 1
 Ratio = $(P_u^2 + M_u^2)^{.5} / (\phi P_n^2 + \phi M_n^2)^{.5}$
 $P_u = 123.076$ k $\phi * P_n = 472.355$ k
 $M_{u-x} = 4.482$ k-ft $\phi * M_{n-x} = -16.664$ k-ft
 $M_{u-y} = 0.0$ k-ft $\phi * M_{n-y} = 0.0$ k-ft
 M_u Angle = 0.0 deg
 M_u at Angle = 4.482 k-ft ϕM_n at Angle = 17.449 k-ft

Maximum SERVICE Load Reactions . .

Top along Y-Y 0.0 k Bottom along Y-Y 0.0 k
 Top along X-X 1.085 k Bottom along X-X 1.085 k

Maximum SERVICE Load Deflections . . .

Along Y-Y 0.004421 in at 5.20 ft above base
 for load combination : +D+H
 Along X-X 0.0 in at 0.0 ft above base
 for load combination :

P_n & M_n values located at P_u - M_u vector intersection with capacity curve

Column Capacities . . .

P_{nmax} : Nominal Max. Compressive Axial Capacity **908.38** k
 P_{nmin} : Nominal Min. Tension Axial Capacity k
 ϕP_n , max : Usable Compressive Axial Capacity **472.355** k
 ϕP_n , min : Usable Tension Axial Capacity k

General Section Information . $\phi = 0.650$ $\beta = 0.8250$ $\theta = 0.80$

ρ : % Reinforcing **1.233** % Rebar % Ok
 Reinforcing Area **2.480** in²
 Concrete Area **201.062** in²

Governing Load Combination Results

| Governing Factored Load Combination | Moment | | Dist. from base ft | Axial Load k P_u | Bending Analysis k-ft | | | | | | Utilization Ratio | | |
|-------------------------------------|--------|-----|--------------------|-----------------------|-----------------------|------------|---------------------|------------|---------------------|-------------|-------------------|-------------|-----------|
| | X-X | Y-Y | | | $\phi * P_n$ | δ_x | $\delta_x * M_{ux}$ | δ_y | $\delta_y * M_{uy}$ | Alpha (deg) | | δMu | ϕMn |
| +1.40D+1.60H | Actual | | 10.26 | 78.63 | 472.36 | 1.000 | 4.48 | | | 0.000 | 4.48 | 27.19 | 0.166 |

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

Project Title:
 Engineer:
 Project ID:
 Project Descr:

Printed: 8 FEB 2022, 5:40PM

Concrete Column

File: 21498 Osprey Ranch Water Tank.ec6
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ARW ENGINEERS

Lic. #: KW-06002489

DESCRIPTION: Columns

Governing Load Combination Results

| Governing Factored Load Combination | Moment | | Dist. from base ft | Axial Load k | | Bending Analysis k-ft | | | | | Utilization Ratio | | |
|-------------------------------------|--------|-----|--------------------|--------------|-------------|-----------------------|------------------|------------|------------------|-------------|-------------------|-----------|--------------|
| | X-X | Y-Y | | Pu | $\phi * Pn$ | δx | $\delta x * Mux$ | δy | $\delta y * Muy$ | Alpha (deg) | δMu | ϕMn | Ratio |
| +1.20D+1.60H | Actual | | 10.26 | 67.40 | 472.36 | 1.000 | 4.48 | | | 0.000 | 4.48 | 31.28 | 0.143 |
| +1.20D+0.50S+1.60H | Actual | | 10.26 | 84.80 | 472.36 | 1.000 | 4.48 | | | 0.000 | 4.48 | 25.74 | 0.178 |
| +1.20D+1.60S+1.60H | Actual | | 10.26 | 123.08 | 472.36 | 1.000 | 4.48 | | | 0.000 | 4.48 | 17.45 | 0.260 |
| +1.20D+0.70S+1.60H | Actual | | 10.26 | 91.76 | 472.36 | 1.000 | 4.48 | | | 0.000 | 4.48 | 23.18 | 0.194 |
| +0.90D+0.90H | Actual | | 10.26 | 50.55 | 472.36 | 1.000 | 2.52 | | | 0.000 | 2.52 | 23.18 | 0.107 |

Maximum Reactions

Note: Only non-zero reactions are listed.

| Load Combination | X-X Axis Reaction | | k | Y-Y Axis Reaction | | Axial Reaction | My - End Moments | | k-ft | Mx - End Moments | |
|------------------|-------------------|-------|---|-------------------|-------|----------------|------------------|-------|------|------------------|-------|
| | @ Base | @ Top | | @ Base | @ Top | | @ Base | @ Top | | @ Base | @ Top |
| +D+H | | | | 1.085 | 1.085 | 56.164 | | | | | |
| +D+S+H | | | | 1.085 | 1.085 | 90.964 | | | | | |
| +D+0.750S+H | | | | 1.085 | 1.085 | 82.264 | | | | | |
| +0.60D+0.60H | | | | 0.651 | 0.651 | 33.698 | | | | | |
| D Only | | | | | | 56.164 | | | | | |
| S Only | | | | | | 34.800 | | | | | |
| H Only | | | | 1.085 | 1.085 | | | | | | |

Maximum Moment Reactions

Note: Only non-zero reactions are listed.

| Load Combination | Moment About X-X Axis | | k-ft | Moment About Y-Y Axis | | k-ft |
|------------------|-----------------------|-------|------|-----------------------|-------|------|
| | @ Base | @ Top | | @ Base | @ Top | |
| +D+H | | | | | | |
| +D+S+H | | | | | | |
| +D+0.750S+H | | | | | | |
| +0.60D+0.60H | | | | | | |
| D Only | | | | | | |
| S Only | | | | | | |
| H Only | | | | | | |

Maximum Deflections for Load Combinations

| Load Combination | Max. X-X Deflection | | Distance | Max. Y-Y Deflection | | Distance |
|------------------|---------------------|----|----------|---------------------|-------|----------|
| | | | | | | |
| +D+H | 0.0000 | in | 0.000 | ft | 0.004 | in |
| +D+S+H | 0.0000 | in | 0.000 | ft | 0.004 | in |
| +D+0.750S+H | 0.0000 | in | 0.000 | ft | 0.004 | in |
| +0.60D+0.60H | 0.0000 | in | 0.000 | ft | 0.003 | in |
| D Only | 0.0000 | in | 0.000 | ft | 0.000 | in |
| S Only | 0.0000 | in | 0.000 | ft | 0.000 | in |
| H Only | 0.0000 | in | 0.000 | ft | 0.004 | in |



Circular Concrete Tanks without Prestressing - 1993 PCA Document

Version Date: September 14, 2010

Author: DOC Reviewed By:

JOB TITLE: Osprey Ranch Water Tank

WALL LOCATION: 0

09-Feb-22

9:28 AM

JOB #: 21498

DESIGNED BY: MOW

| | | |
|-------------------|-------------|-------------------|
| D _{tank} | 70 | ft |
| H _L | 10.33 | ft |
| g | 32.17 | ft/s ² |
| λ | 7.657462694 | |
| T _C | 6.865054648 | s |
| S _{D1} | 0.364 | g |
| S _{DS} | 0.81 | g |
| T _S | 0.449382716 | s |
| C _C | 0.04124851 | |
| I | 1.5 | |
| d _{max} | 2.165546764 | ft |

Required Freeboard

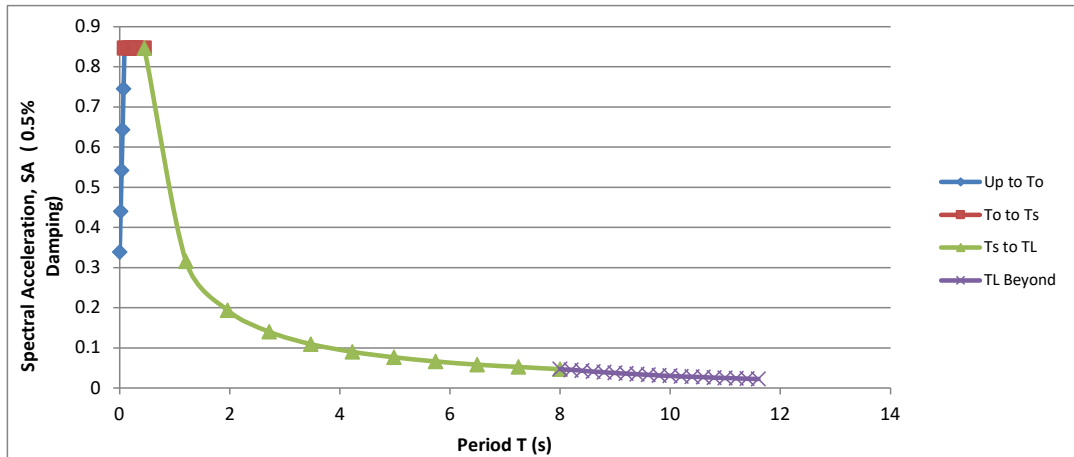
| | | |
|-------------|-------------|---------|
| Tank Volume | 250000 | Gallons |
| Ht to Water | 8.684072089 | ft |

| | | |
|--------------------|------|----|
| New H _L | 8.68 | ft |
| New d _f | 1.65 | ft |

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

| | | |
|----------------|-------------|----|
| h _n | 9.35 | ft |
| T | 0.106939637 | s |
| T _o | 0.089876543 | s |
| T _L | 8 | s |
| S _a | 0.405463317 | g |
| S _a | 0.81 | g |

height above base to highest level of structure
 Approximate Fundamental Period as Per ASCE 7 eqn 12.8-7
 Per ASCE 7
 Per ASCE 7 (fig 22-15)
 For periods less than T_o
 For periods >= to T_o and <= to T_s



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

| | | | |
|--------------|-------------|-----------------------|--|
| SA (T_c) | 0.053022156 | g | Spectral Acceleration at T_c |
| Theta | 3.035103656 | degrees | Angle of free surface at sloshing load |
| h_r | 1 | ft | height from top of wall to underside of topmost point of lid |
| V_{EMPTY} | 7632.761151 | ft ³ | Empty Volume of tank above water |
| d | 1.855775468 | ft | Vertical displacement of liquid surface |
| d_r/d | 0.889116183 | | |
| h_r/d | 0.538858293 | | |
| X_f/R | 0.1 | | |
| X_f | 3.5 | ft | |
| ρ | 1.94 | slugs/ft ³ | mass density of liquid |
| P_{max} | 6.60 | psf | Weight of Roof is heavier, therefore ok |
| F_{max} | 11.55 | plf | #5 Radial Dowels @ 8" o.c. okay (Roof Slab to Wall) |

Fig 6 from "Earthquake Induced Sloshing in Tanks with insufficient Freeboard"

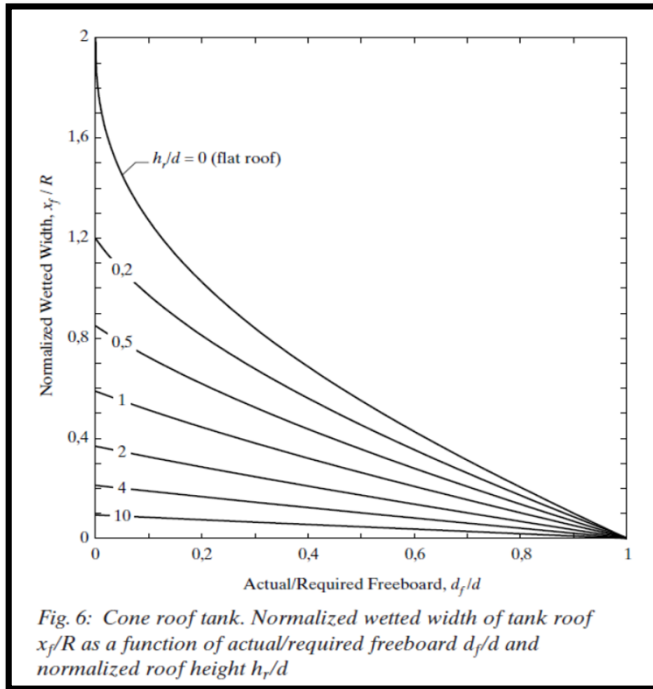


Fig. 6: Cone roof tank. Normalized wetted width of tank roof x_f/R as a function of actual/required freeboard d_r/d and normalized roof height h_r/d

Weight

| | | | | |
|--------------------------------|-------------|-----------------------|--------------------|----------|
| D/H _L | 8.064516129 | | | |
| W _i /W _L | 0.17 | PCA EB219 fig 4-4 (b) | | |
| W _c /W _L | 0.76 | PCA EB219 fig 4-4 (b) | | |
| W _L | 2171 kips | Weight Of Water | | |
| W _i | 369 kips | Impulsive Weight | | |
| W _c | 1650 kips | Convective Weight | | |
| T _w | 12 inches | Wall Thickness | D _{outer} | 72.00 ft |
| T _r | 8 inches | Roof Thickness | | |
| W _w | 346 kips | Weight of Walls | | |
| W _R | 407 kips | Weight of Roof | | |

Period

| | | | | |
|----------------|--------------------------|-----------------------------|--|--|
| C _w | 0.117 | PCA EB219 fig 4-10 | | |
| C _L | 0.20 | | | |
| E _c | 3824 ksi | Elastic Modulus of Concrete | | |
| ρ _c | 4.66 #-s/ft ⁴ | Mass Density of Concrete | | |
| ω _i | 247.6733874 rad/s | | | |
| T _I | 0.03 s | | | |

Base Shear

| | | | | |
|-----------------------|----------|------------------------------|--|--|
| R | 1.5 | Response Modification Factor | | |
| C _{si} | 0.81 | | | |
| C _{si (min)} | 14.35 | | | |
| C _{sc} | 0.81 | | | |
| C _{sc (min)} | 0.05 | | | |
| V _i | 909 kips | Impulsive Base Shear | | |
| V _c | 87 kips | Convective Base Shear | | |
| V _T | 913 kips | Total Base Shear | | |

Overturning Moment

| | | |
|-----------|-------------|--------------------------|
| h_i/H_L | 0.38 | PCA EB219 fig 4-5 (b) |
| h_c/H_L | 0.54 | PCA EB219 fig 4-5 (b) |
| h_i | 3.2984 ft | |
| h_c | 4.6872 ft | |
| h_w | 5.165 ft | |
| M_i | 5839 kip ft | Impulsive |
| M_c | 518 kip ft | Convective (Per ACI 350) |
| M_T | 5862 kip ft | Total |

Overall Stability Check

Sliding (Neglecting Backfill)

Weight of tank w/out contents:

| | |
|----------------|----------------|
| Walls | 346 kips |
| Roof | 407 kips |
| Columns | 19 kips |
| Base Slab | 396 kips |
| Water | 2171 kips |
| Total Weight | 3339 kips |
| Friction Coeff | 0.35 |
| Base Shear | 913 |
| Safety Factor | 1.280278195 ok |

Overturning

| | |
|---------------|---------------|
| OTM | 5862 kip ft |
| RM | 116881 kip ft |
| Safety Factor | 19.9 ok |

Design of Walls for In-Plane Loading

| | | |
|------------|--------------|---------------------------|
| V_u | 913 kips | Base Shear |
| V_c | 6.6 kips/ft | Shear in wall |
| α_c | 3 | See ACI 318 eqn 18.10.4.1 |
| ρ_t | 0.004306 | See ACI 318 eqn 18.10.4.1 |
| ϕV_n | 48.4 kips/ft | ok |

#5 at 12" oc EF

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