OSR 45-24 (Rev 1-20-2009)

Calculation Cover Sheet

Project/Task Z-Area Saltstone Storage Tanks	Calculation No. T-CLC-Z-00022	Project/Task No. PO # WB00001K
Title Evaluation of Selected Values from CROM's Calculation for the Z-Area Saltstone Storage Tanks (Vault 2)	Functional Classification PS Discipline CSA & SM	Sheet 1 of 37
Calculation Type ☑ Type 1 ☐ Type 2	Type 1 Calc Status ☐ Preliminary ☑ Confirmed	
Computer Program No. N/A	Version/Release No. N/A	
Purpose and Objective Generate an alternate calculation to verify selected values for the wall in CROM's proprietary computer program output file [1] for Vault 2.	DC/RO N/A	Date

Summary of Conclusion

Since the alternate calculated values (see Section 4.0) herein are approximately equal to selected values from CROM's proprietary computer program output, the calculation is considered to be acceptable (calculation filed under PO # WB00001K, Sheet 6). See Section 3.0 for evaluation.

Revisions

Rev #	Revision Description
0	See sheet 2

Sign Off

Rev #	Originator (Print) Sign/Date	Verification/Checking Method	Verifier/Checker (Print) Sign/Date	Manager (Print) Sign/Date
0	Ramesh Patel Ramesh Patel 9/28/09	☐ Design Check (GS/PS only) ☑ Document Review ☐ Qualification Testing ☐ Alternative Calculation ☐ Operational Testing	Wade Faires, W. Faires 9/28/09	Wade Faires W. Faires 9/28/09

Role (Print)	Signature	Date
Additional Reviewer (Print): N/A	N/A	N/A
Design Authority (Print): Coleman Miles		
Release to Outside Agency (Print): N/A	N/A	N/A

Security Classification of the Calculation

Unclassified

RECORD OF REVISIONS

Revision	Description	Pages Affected
0	Original Issue –	All

OPEN ITEMS

None

TABLE OF CONTENTS

1.0 Purpose and Scope

CROM Corporation has a proprietary computer program that analyzes the two 2,900,000-Gallon Saltstone Storage Tanks (Vaults 2A and 2B), which are currently being built in Z-Area at the Savannah River Site (SRS). This program was used to generate a tank design calculation, which is filed as Purchase Order No. WB00001K, sheet 6B [1]. This calculation contains input and output files, but no detailed calculations with equations, that a Non-CROM Engineer could sit down and readily compute the output values shown in the output file. CROM did have calculations with equations that designed/evaluated the bottom slab, columns, column supported roof slab, settlement, and openings.

The tanks are Production Support (PS) and Performance Category 2 (PC2), which requires they be designed to the IBC Code [2].

The Department of Energy (DOE) has asked Savannah River Remediation (SRR) Project Team for Vaults 2A and 2B how the output portion of the proprietary program was verified. SRR raised the same question during its review process. CROM stated that the program was proprietary; therefore, SRR verified the input and accepted the calculation as is for several reasons cited below.

1) CROM, which has been in business since 1953, is one of the leading Companies in the design and construction of these type tanks.

2) CROM's Senior Vice-President and Area Manager for North and South Carolina performed an alternate calculation using an EXCEL spread sheet. A portion of this alternate spread sheet calculation is included in Section 3.1 to this calculation to verify selected values in the output file (Appendix A). Section 4.1 compares values from Appendix A to those from the alternate calculation in Section 3.0. The results are reasonably close.

3) CROM was involved in the design and construction of the current Type IV Tanks (17 through 24), which have a singe wall with a steel liner, prestressed wires and shotcrete.

4) Prior to CROM designing the Vault 2 tanks, SRR generated a structural performance assessment calculation [3], which performed a long-term assessment of the structural behavior of the proposed configuration for Vault 2.

Therefore, since CROM is considered one of the leading Companies in the design of this type of tank and they were contracted to design the SRR Vault 2 tanks, the calculation was originated/verified by two PEs, and an independent CROM calculation was generated, SRR did not feel that a line-by-line list of equations showing computation of output values was necessary. The output values presented in CROM's calc were judged to be reasonable based on the input values provided; input values were verified as correct based on requirements provided.

However, to address DOE's concerns, an alternate calculation is performed herein to verify selected values for the wall from the program output file (Appendix A).

In addition to the computer files, CROM used MATHCAD for the design of the columns, bottom slab, roof slab, and allowable settlement of the base slab based on ACI 372. Therefore, verification of these calculations is not required, as well as the seismic loads for reasons cited in the methodology section.

2.0 Methodology/Input/Assumptions

2.1 Methodology

CROM's calculation in Appendix A used ACI 372R, 350 & 318 [4, 5 & 6] to design the single wall Vault 2 tanks. The alternate calculation in Section 3.1 references AWWA D110 [7], ACI Committee Report No. 344R [8], and Timoshenko's Theory of Plates and Shells [9]. The codes and reports used in Appendix A are equivalent to the codes, reports and references used in Section 3.1. In fact, AWWA D110 cites ACI 372R, 350 & 318 to be used for certain tank attributes. Either is acceptable and will produce equivalent results as shown herein. Appendix A used a proprietary computer program to design the tanks. The CROM Senior Vice-President and Area Manager used an alternate Excel spread sheet calculation to verify the results in the main calculation, of which, some portions are included in Section 3.1. In Reference 1 various input parameters for the tank are listed, some of which are listed in Section 2.2. Based on this input, the program provides various tank parameters (wall thickness, number and size of wires, number and size of rebar, their placement, prestress requirements, shotcrete requirements, etc.) for developing a tank drawing used to fabricate the tanks.

As stated above some of the key output values from the program are verified using the equations below. Some key values are number of prestress wires, thickness of concrete, stress in the wall, and required steel.

$T = pR = Nw*Aw*fs$ (equ 1) $Nw = pR \div Aw*fs$ (equ 2)

$Nw*Aw*fs = tc*f'c$ (equ 3) $tc = Nw*Aw*fs \div f'c$ (equ 4)

$f'c = Nw*Aw*fs \div tc$ (equ 5)

Where:

T = tension in wall, p = pressure, R = tank radius, Nw = number of wires, Aw = area of wire, fs = wire yield strength, tc = thickness of concrete, f'c = compressive strength of concrete.

As explained by CROM's Area Manager, several key calculations are made to determine the wall details. They are:

1. Determine the internal outward force caused by hydraulic pressure.
2. Determine the number of wires needed to balance the outward force. In calculating the number of wires, the wire stress is reduced to account for losses due to shrinkage, creep, and relaxation of the wires. Also, calculate the number of wire needed to place the wall in compression. The total of both is used to calculate the wall thickness.
3. Calculate the wall thickness at the top and bottom needed to resist the stress caused by the number of wires calculated in step 2. In addition, calculate the additional wall thickness needed to resist the soil backfill load.
4. Calculate the bending in the wall due to temperature differences between the interior and the exterior and provide vertical reinforcement to resist bending.
5. Calculate the bending in the wall due to partial restraint at the bottom of the wall and provide vertical reinforcement to resist the bending.
6. Determine the loads due to seismic. Wind is shown in Section 3.9 not to control.
7. Combine the appropriate prestress, stress, and/or loads [(initial stress in wall + soil backfill stress with tank empty) and (internal load/stress + seismic loads/stresses with tank full)]
8. Determine size, number and spacing of vertical rebar (two rows) to take (initial prestress + soil backfill), (initial prestress + seismic), and (initial prestress + thermal)

CROM adds extra circumferential reinforcement at the top and bottom of the tank wall to control cracking. This is usually 1% of the wall area encompassing the reinforcement.

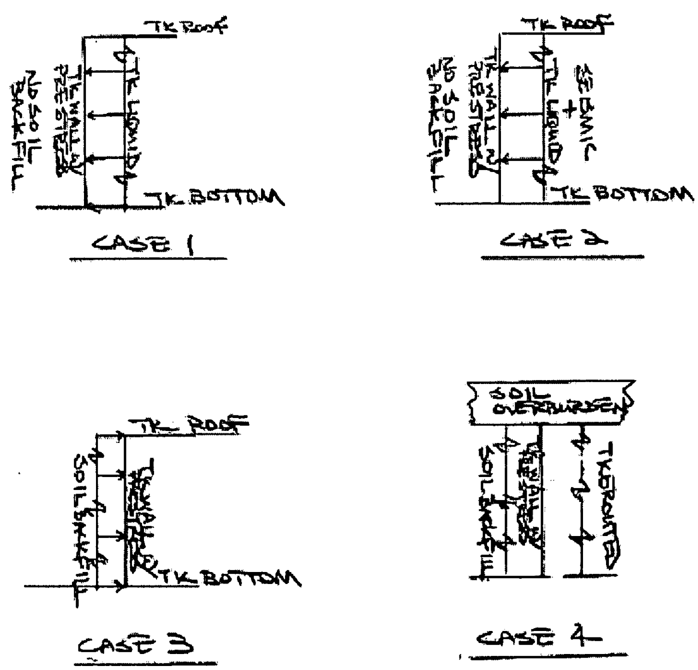
CROM's calculation evaluated the tank for three load cases, which are described below and supplemented with sketches. A fourth load case is with the tank grouted, which was evaluated in this calculation, but not in Appendix A.

1. Tank full of liquid, walls prestressed, and no soil backfill,

2. Tank full of liquid, walls prestressed, no soil backfill, and seismic,

3. Tank empty, walls prestressed, and soil backfill,

4. Tank grouted, walls prestressed, soil backfill, and soil overburden.



Load Case Diagrams

CROM did not evaluate the load case with tank full of grout, walls prestressed, soil backfill, and 13 feet of soil overburdened, since the tank behaves as a rigid body. See seismic evaluation for this case below.

Of the four load cases evaluated, Load Case 3 controlled.

CROM was asked to design the tank for seismic loads using PS, PC2 seismic requirements. CROM's seismic load includes the prestressed walls, static water pressure load plus seismic hydrodynamic sloshing loads from water inside the tank (due to hydrostatic testing of tank for leaks). See pages 4 through 8 of their calculation. Also, when saltstone is added in lifts that solidify in approximately 1 feet increments, liquid sloshing is not an issue. Therefore, since it's judged that the real seismic load on the tank is the solidified grout, verification of CROM's seismic analysis will not be done herein. Rather, a justification why seismic is not the critical load case will be provided here. As stated, the grout is a solid mass, which is considered to be rigid (> 33hz). From T-CLC-G-00261 [10], Table 3.1.1, the seismic acceleration is 0.33gs. From DOE/EH-0545 (Seismic Evaluation Procedure), [11], Section 9.1.1.4, uses a coefficient of friction of 0.55 for a steel tank resting on a concrete foundation. Since 0.33gs is less than 0.55, the solid grout content will not slide and induce loads on the tank wall. Therefore, the analysis that CROM did for the tank wall is conservative. If ever required, credit for the columns doweled into the roof slab and floor slab could be used to resist lateral seismic loads. Also, the tank walls have a lateral seismic restraint system.

The wall of the tank uses working stress methodology, which doesn't require load factors on various loads. The roof, columns, and slab use strength design, which requires load factors on various loads.

2.2 Input

Some key input parameters for the tank and the proprietary program are listed below:

1. Tank size and Content = 150 ft diameter, 22 ft height, Water specific gravity = 62.4 pcf, Sp Gravity = 1.32, t_{diff} = thru wall temperature differential = 100 °F (conservatively assumed).
2. The tank is constructed of prefab concrete wall panels with prestressed wires, reinforced concrete roof supported by wall and reinforced concrete interior columns, and reinforced concrete slab.
3. t_{fl} = floor slab thickness = 8 inches and rise in floor at edge (wall) is 3 inches.
4. f'c = floor slab compressive strength = 5 ksi.
5. f'g = shotcrete compressive strength = 4.5 ksi. This is the average of wall concrete compressive strength (5 ksi) and shotcrete (4 ksi).
6. f'c-r = residual compression in the concrete wall = res = 0.2 ksi. (Per ACI 372R, Section 2.3.5.2).
7. Eg = shotcrete modulus of elasticity = 4500 ksi
8. Et = shotcrete modulus of elasticity for temperature = 2000 ksi
9. f'g-i = initial prestress = (0.55)(f'g) = 2.475 ksi (ACI 372, section 2.3.3.2.1).
10. f'g-f= final prestress = (0.45)(f'g) = 2.025 ksi
11. fs = allowable stress in mild steel = 18 ksi (ACI 372, section 2.3.7.1)
12. Prestress wire gauge = #8, d = 0.162", A = 0.0206 in^2, Fu = ultimate strength = 231 ksi, Fi = initial prestress = 145.6 ksi, $F_{f\text{-}w}$ = wall final prestress = 121 ksi (145.6 – 24.6)
13. $fs_{\text{-}loss}$ = prestess loss = 24.6 ksi (ACI 372, section 2.3.5.3)
14. V = wind speed = 150 mph, I = 1.15 is listed in Appendix A. Per CROM, the wind demand force is not checked, since wind never controls. See Section 3.9 for quantitative justification.
15. ε = average shrinkage = 0.00080 in/in
16. Ccr = average creep = 0.0000003 in/in/psi
17. $\propto t$ = Coefficient of thermal expansion = 0.0000065 in/in/°F
18. Wall details are in PO # WB00001K, Sheet 4E (sheet 6 of 15).

To understand the design philosophy and criteria with respect to these types of tanks and to help formulate this calculation, the originator & checker from Design Engineering has had several meetings (8/11/09, 9/3/09 and 9/24/09) and telecoms (8/27/09, 8/31/09 & 9/1/09) with CROM's VP and Area Manager. He and Ryan Harvey prepared the alternate calculation in Section 3.1.

2.3 Assumptions

As noted in the calculation.

3.0 Calculations

This section verifies selected values of the output file on pages 2, 3, and 4 of CROM's calculation [1], which have been included in Appendix A (pages A3, A4, & A5). Arrows are annotated in the margin for those values that are evaluated in this calculation. To help perform this verification, CROM provided an alternate excel spread sheet calculation with appropriate equations, which computes/validates most of the values (selected to be verified) from Reference 1. This calculation is provided in section 3.1, since it closely follows the design steps outlined in the methodology section. Section 3.2 shows detailed computations for some of the values in Section 3.1. The correlation between the two sections is either the section number or number in brackets in the right margin of CROM's calculation. To verify some other values in Reference 1, SRR Design Engineering generated the calculations in Sections 3.3 through 3.10.

A comparison of the results is presented in Section 4.1, Table 1.

3.1 CROM Alternate Calculation

This section contains the alternate calculation (4 pages) by CROM, which verifies selected values from pages 2, 3, and 4 of Reference 1, which are included in Appendix A (pages A2, A3, A4, & A5). This calculation, which was transmitted by an email on 9/9/09, was originated by Lars Bálck and checked by Ryan Harvey of CROM Corporation. The format follows the methodology discussed above for evaluating critical attributes of the tank. Input values highlighted in yellow are input from Section 2.2, the tank drawings, specification, and/or assumption. Equations for computing some of the values are annotated to the right of the computed value. Section 3.2 shows detailed computations for some of the values in Section 3.1. The correlation between the two sections is either the section number or the number in brackets in the right margin of CROM's calculation (pages 12 – 15). This number is shown in bold in Section 3.2 (pages 16 – 18). Section 3.2 shows the equations with computations used to compute the value in Section 3.1.

9/24/2009

---- PRESTRESSED TANK DESIGN ----

Prepared by : Lars Balck

Project name : SRS
Tank description : 3.0-MG Vaults
Engineer : SRS
Job No. : 6059

"SUPERSTOP DESIGN OF PANEL TANK"

The design of the circular wall is based on ACI Committee Report No. ACI 344-70, AWWA D110 Type II, or more stringent Crom criteria. Wall stresses and bending moments are calculated from Timoshenko's Theory of Plates and Shells equations.

TANK DIMENSIONS:

Inside Diameter, ID :	150.00	ft				
Sidewall Depth, SWD :	22.00	ft	Capacity =	2,908,194	gal	
Flr-Ftg Diff :	3.00	in	Wall Height, H =	21.75	ft	
Sp gr :	1.32		Unit wt of liquid =	82.37	pcf	lateral pressure
			Unit for seismic/floor =	112.00	pcf	vertical pressure

SHOTCRETE, STEEL & P/S STRESSES & MISC:

f'g :		4,500	psi	
Max fg :	0.45	2,025	psi	
Max fgi :	0.55	2,475	psi	
fs :		18,000	psi	
Wire gauge, GA:		8		dwg
Cover Coat Thickn,TCC :		1.00	in	dwg
Thickness Betn Layers :		0.125	in	
Top Core Thk, TCT :		9.00	in	dwg

ADDITIONAL INPUT :

Delta T, TC :	100	degrees	spec	
Height of Backfill, HB :	21.75	ft	dwg	
unit wt:	125.00		spec	
factor:	0.75			
Backfill Unit Weight, den :	93.75	pcf		Section 3.8
Residual compression, res :	200	psi	spec	
wt of roof/sf:	100.00			
dist to columns:	20.00			
Roof load per lf on top of wall =	1,340	plf	wt/sf*dist*2/3	

WIRES & COREWALL CALCULATIONS:

Wire fsi =	145,600	psi	dwg	
Wire Dia, dw =	0.162	in	dwg	
Wire Area, Aw =	0.0206	in^2	dwg	
Wall Losses =	24,600	psi		
Wire fs Wall, fs =	121,000	psi	fsi-wall loss	
Total t top, twt =	11.000	in	dwg	
Number wire ps =	53.90	wires	Wires to resist hydraulic force unit wt*(H)*R/Aw*fs	
Number wire res =	11.79	wires	Wires for residual compression tcw*12*res/Aw*fs	
Total number wires, N =	65.7	wires	Wires needed to resist hydraulic force + residual	[1]
H^2/Dt =	3.09			[13]

PRESTRESSED TANK DESIGN
SUPERSTOP FLOOR-WALL JOINT

- 2 -

THE CROM CORPORATION
9/24/2009

Maximum fg =		2,025	psi				
Maximum fgi =		2,475	psi				
fg Used =		2,025	psi				
fgi Used =		2,475	psi				
tcw =		12.25	inch	trial thickness			[2]
	initial	final		thickness			
ps	1,341	1,114	psi	8.11	in	Nw*Aw*Fs/12/fg	[3], [4], [5]
bf	0	893	psi	4.21	in	p*h*R/fg/12/(tc+tcc)	[6], [7]
Total fg	1,341	2,007	psi	12.32	in		
Allowable fg	2,475	2,025	psi				

WEIGHT & WALL THICKNESS CALCULATIONS:

Covr Coat t @ Bot, tfc =	1.99	in	dwg	[8]
t,full @ Bot, tfb =	14.24	in	(12.25 + 1.99)	
Average "t", full, tavg =	12.62	in	(11 + 14.24)/2	
Wall weight =	3,430	lb		
Roof weight, Dwgt =	1,340	lb		
Total Wall Weight =	4,770	lb	(3430 + 1340)	Section 3.5
Bearing pad width =	6	inch	dwg	
Unit Load on Pad =	66	psi, o.k.		[9]

RADIAL DEFLECTION & SHEAR CALCULATIONS:

fg =	2,007	psi		
P/S "w" =	99.11	pcf		[10]
Backfill "w" =	93.75	pcf		[10]
Res. Stress "w" =	18.45	pcf		[10]
Equiv. "w" =	211.31	psf	(99.11+93.75+18.45)	
Friction Coef., VCF =	0.70			[12]
Total V =	3,339	lb	vcf*wall weight = (0.7)(4770)	
Delta p =	0.40	in	fg*R/Eg/12	[11]
Delta s =	0.72	in	.0008*12*R	[11]
Delta c =	0.54	in	fg*R*.0000036	[11]
Total	1.66	in	(0.4+0.72+0.54)	

CALCULATE MOMENTS AND STEEL REQUIREMENTS:

Inside Moment =		7,217	ft-lb	.247*V*sqrt(R*tcw)				[13]
Occurs at =		5.25	ft	.6*sqrt(R*tcw)				[13]
Inside "d" =		10.25	in	dwg				[13]
Provided	spacing							
Resteel =	6.00	0.536	sq in	#6	0.88	OK		[14]

Outside temperature cold, inside warm.

avg "t" =			12.62	in	(thick top +thick bot)/2		
T Coeff =			7.36		Appendix B		[15]
Outside Moment =			10,573	ft-lb	temp coef*.0000065*2000000*tcave^2*deltaT/12/12		[15]
Provided	spacing	sq in		Outside "d"			
#6	4.50	0.827		7.25	7,866	As*.875*18000*d/12	
diaphragm		0.26		8.25	2,761	As*.875*18000*d/12	
				15.50	10,627	OK	

Bottom Circ. =	4.77	sq in	0.01	bottom 3 ft	Section 2.1
Top Circ. =	2.46	sq in	0.01	top 2 ft	Section 2.1

Size floor edge to match typical soil pressure :

Concrete strength =	5,000	psi	dwg		
Edge of slab thickness, Edge_t :	11.00	in	dwg		
Typical slab thickness, tfl :	8.00	in	dwg		
Dist fr ID to inside end of flat edge :	1.16	ft	dwg		
Grout + Slab Pressure =	2,564	psf			[16]
Wall Weight =	4,770	plf			
Slab Edge Wt. Pressure =	138	psf			[17]
Net Pressure Allowed =	2,427	psf			[17]
Required Bearing Width =	1.97	ft			
Width from ID to Outside Edge of Slab =	2.28	ft			
Width fr ID to Outside Edge, 1'4" min =	2.28	ft			
Length of Flat Edge =	3.44	ft			
Selected Length of Flat_Edge :	3.76	ft	dwg		
Resulting Width from ID to Outside Edge	2.60	ft			
Resulting Pressure =	1,208	lb/ft			[18]
Shear on Footing =	3,140	lb			[18]
Shear Stress =	23.79	**< 70 psi, o.k.**			[18]
Moment on Footing =	4,082	ft-lb			
Required Floor Steel =	0.37	in^2/ft	spacing	#	
Steel Provided =	0.99	**in^2/ft, o.k.**	7.50	5	

SEISMIC

Unit wt	113.00	
Mass	328,625,956	
Friction factor	0.50	
No. columns	48.00	dwg
Diameter	14.00	dwg
Allowable shear	70.00	
Impulsive shear	0.26	From seismic calculations
Base shear	85,442,749	

DATA TABLES:

Bar Size	db	Ab	wtb
0	0.000	0.000	0.000
3	0.375	0.110	0.376
4	0.500	0.200	0.668
5	0.625	0.310	1.043
6	0.750	0.440	1.502
7	0.875	0.600	2.044

Wire Data:

fsi =	dw =	Aw =	Guage	Wires/ft	Losses
0	0.000	0.000	2	0	0
0	0.000	0.000	4	0	0
140,000	0.192	0.029	6	20	25,000
145,600	0.162	0.021	8	24	30,600
0	0.000	0.000	10	0	0

fc	4,500.00	
Ec	3,823,676	psi/deg
age adjust	0.50	
E age adj	1,911,838	
t coef	0.0000056	
v	0.17	
Ealpha/v	0.10	
delta t	100.00	deg
tave	13.00	in
	1,690.00	psi*in^2

3.2 Detailed Computations for Values in Section 3.1

The calculation in Section 3.1 was generated using an excel spread sheet. The spreadsheet provided some equations just to the right of the value, but not all. Thus, the equations and computations for some of the values are provided in this section. The numbers in brackets correspond to those in the right margin of CROM's calc in Section 3.1.

(1) Justification for 81 wires at the Bottom of the Wall

Per the calculations in Section 3.1, the total number of wires required is 65.7 for a 12 inch high section of wall. Sheet 7 of CROM's tank drawing shows 81 wires are required for a 15 inch (12 inch + 3 inches) high section of wall. The 81 is determined by multiplying 65 by 1.25 (ratio of 81/65).

(2) Trial Thickness

An initial trial thickness of 12.25 inches is used. This was determined from the equation below , which is a modification to the equation in AWWA D110, page 22. CROM uses fgi = 2169 psi in lieu of 0.45f'c = 2025 psi.

$$\text{fgi} = 2169 \text{ psi} = 1250 + 75(\text{tcw}) \qquad \text{tcw} = (2169 - 1250)/75 = 12.25 \text{ in}$$

(3), (4) & (6) Initial and Final Prestress for 65.7 Wires (for hydro load and residual wall stresses)

The initial prestress for 65.7 wires is computed below using fsi = 145,600 psi and Equ 5 from Section 2.1

$$\text{psi} = (\text{Nw})(\text{Aw})(\text{fsi}) \div (12)(\text{tcw}) = (65.7)(0.0206 \text{ in}^2)(145{,}600 \text{ psi}) \div (12)(12.25") = 1341 \text{ psi}$$

The final prestress for 65.7 wires is computed using fsi = 121,000 psi and Equ 5 from Section 2.1

$$\text{psf} = (\text{Nw})(\text{Aw})(\text{fs}) \div (12)(\text{tcw}) = (65.7)(0.0206 \text{ in}^2)(121{,}000 \text{ psi}) \div (12)(12.25") = 1114 \text{ psi}$$

$$\text{bff} = \rho * H * R \div (12)(\text{tbf} + \text{tcc}) = (93.75 \text{ pcf})(21.75')(75') \div (12)(12.25 + 2) = 895 \text{ psi}$$

(5) & (7) Trial Thicknesses for ps and and bf

This is an independent check by CROM to determine, out of the total thickness, the thickness required for prestressing and for backfill.

tps = (Nw)(Aw)(fsi) ÷ 12(fg) = (65.7)(0.0206)(145600) ÷ 12(2025) = 8.11

fg = ρ*H*R ÷ (12)(tbf + tcc) Solve for tbf, using tcc = 2" and H = 21.75' – 1'/2 = 21.25'

tbf = [ρ*H*R ÷ (12)(fg)] – tcc = (93.75 pcf)(21.25')(75') ÷ (12)(2025 psi)] – 2 = 4.15"

(8) Cover Coat at Bottom

Per sheets 6 & 7 of CROM drawing 08084SD, Rev B & excluding thickness of seismic restraint;

tfc = 1" + (3 wire layers)(.162) + (3 spacing between wires)(.125) = 1.9 in

(9) Unit Load on Pad at Base of Wall

Per sheets 6 & 7 of CROM drawing 08084SD, Rev B, the pad that the wall rests on is 6 in effective width.

fbw = wall bearing pressure on pad = 4770 plf ÷ (6")(12 "/' length of wall) = 67 psi

(10) "w", Equivalent Density Checks

In Section 3.1, CROM generated an equivalent density check, "w", for Prestress, backfill, and Residual stress for comparison. These values are not used, so they are not verified herein. If they were to be verified, the equation below could be used, using the appropriate thickness and pressure.

tbf = [ρ*H*R ÷ (12)(fg)]   (from check [5] above)

ρ = (tbf)(12)(fg) ÷ (H*R)

(11) Deflection Check

The deflections computed using the equations in Section 3.1 are 0.4 in (prestress & backfill), 0.72 in (shrinkage), and 0.54 in (creep). The total deflection is 1.66 in. Based on the water stop used at the base of the wall and experience, CROM said this was acceptable.

(12) Friction Coefficient, VCF

CROM uses a friction coefficient of 0.7 at the base of the wall based on the SuperStop material being used. This is multiplied by the total wall weight, 4770 lbs to obtain the shear, V = 3339 lbs, at the base of the wall. This shear is used in computing the moment to size the vertical reinforcement. See Check (13) below.

(13) & (14) Moment and Reinforcement Requirements for Prestress and Backfill

Using V from above, the moment is computed using the equation, $(0.247(V)(R*t)^{0.5}$, which comes from a Portland Cement Association (PCA) document, "Circular Concrete Tanks Without Prestressing", [12]. The publication states the maximum moment occurs approximately 76% from the top of the tank, which is approximately 5.25 ft from the bottom (76% & 5.25'come from Appendix A, page A5). The development length for the vertical inside steel is given by the equations, $(1.4(Rt)^{0.5}$ and $(1.8)(Rt)^{0.5}$, 12.25 ft and 15.75 ft.

$$M = (0.247)(V)(R*tcw)^{0.5} = (0.247)(3339 \text{ lbs}) [75 \text{ ft} *(12.25" \div 12"/')]^{0.5} = 7217 \text{ ft-lbs}$$

Using the moment, the required steel area is computed using the equation below, which is based on working strength.

As = required steel area
$= (M)(12 \text{ "/'}) \div (j)(Fs)(d) = (7.217)(12 \text{ "/'}) \div (0.875)(18\text{ksi})(10.25 \text{ in}) = 0.54 \text{ in}^2$

This requires #6s at 4.5 in spacing

The equation $H^2 \div D*t$ is used in combination with the moment equation above. This values is $(21.75)^2 \div (150)(12.25/12) = 3.09$

(15) Moment and Reinforcement Requirements for Temperature

The differential temperature, DeltaT, was taken as 100 °F, which puts the outside vertical bars in tension. To compute this moment, the equation below is used. Using $(H^2 \div D*t) = 3.09$ and table on Page B8, T Coeff = 7.36. αt and Et are defined in Section 2.2.

$$M = (T\ Coeff)(\alpha t)(Et)(tavg)^2 (DeltaT) \div (12)^2$$
$$= (7.36)(0.0000065 \text{ in/in/°F})(2{,}000{,}000 \text{ psi})(12.62 \text{ in})^2 (100 \text{ °F})(12) \div (12")^2$$
$$= 10{,}582 \text{ ft-lbs}$$

As is computed using the above equation, $(M)(12 \text{ "/'}) \div (j)(Fs)(d)$. The required steel is comprised of rebar and the vertical 26 gage steel liner.

(16) & (17) Grout + Slab Pressure and Net Pressure

Grout + Slab Pressure = (150 pcf)(8"/12"/') + (113 pcf)(21.75') = 100 psf + 2458 psf = 2558 psf

The Slab Edge Wt Pressure = (150 pcf)(11"/12"/') = 138 psf

The Net Pressure Allowed = (Grout + Slab Pressure) – (Slab Edge Wt Pressure)
= 2558 – 138
= 2420 psf

(18) Shear on Outer Footing

The shear on the outer footing is based on the distribution of the wall load at the bottom of grade. The wall width is 14.24 in and the slab thickness is 11 in.

The effective slab width for computing soil bearing pressure = (14.22"/12"/') + (2)(11"/12"/') = 3.02 ft.

The resulting pressure = 4770/3.02 = 1560 psf,

The distance from the outer edge of the tank wall to the outer edge of the footer = [3.75' – 1.16' – (14.24"/12"/')(1/2)] = 2.0 ft

The shear at the outer edge of the wall = (1560)(2')(1' width) = 3120 lbs

The shear on the footing = (3120 lbs) ÷ (11")(12") = 23.7 psi vs 23.79 psi

The Moment at the edge of the wall = (3120 lbs)(2'/2) = 3120 ft-lbs vs 4082 ft-lbs
Therefore, the moment in Section 3.1 is conservative.

Based on the computations in this section (3.2), the values in Section 3.1 are acceptable, and these values will be compared to CROM's computerized values in Section 4.1, which were obtained from Appendix A.

3.3 Total Bottom Slab Thickness = 8 inches and 11 inches (8 + 3 rise) at the walls.

3.4 Wall thickness = 11 inches (8 + 3 for wires & cover) at top and 15 inches (8 + 7 for wires & cover) at the bottom.

3.5 Wall Weight (5240 plf)

tw_{avg} = (11 + 15)(1/2) = 13"

Ww = weight of wall = (0.15 kcf)(13"/12''/')(22') = 3.56 klf

Wr = weight of roof on wall = (0.15)(8"/12"/')(20'span ÷ 2) = 1.0 klf

Wt = total wall weight at bottom slab = 4.56 klf vs 5.24 klf

3.6 Net Wall Pressure at Floor (1.768 klf)

The calculated bearing width is 2.964 ft at the wall.(from CROM's output)

Therefore, Wpt = bearing pressure = Wt ÷ 2.964 = (5.24 ÷ 2.964) = 1.768 klf

3.7 Unit Weight of Content (82.056 pcf and 112.3 pcf)

Wuw = unit weight of content = (1.32)(62.4) = 82.4 pcf

Wg = unit weight of grout = (1.8)(62.4) = 112.3 pcf

3.8 Unit Weight of Soil Backfill (93.7 pcf)

From the SOW, the unit weight of soil is 125 pcf, the active earth pressure coefficient, Ka = 0.33, and the at-rest earth pressure coefficient, Ko = 0.5. To check the wall, Ka is to be used. However, CROM has arbitrarily used Ka = 0.75, which gives a soil pressure of 93.7pcf. This is conservative and accounts for construction dynamic loads.

3.9 Wind Evaluation (150 mph)

Per Section 2.2, Item 14, V = wind speed = 150 mph, I = 1.15 is listed in Appendix A. Per CROM, the wind demand force is not evaluated, since wind never controls on any of their tank designs. This is primarily due to the mass of the tank and its contents. A quantitative justification is provided below, since the North side of these tanks could be exposed for up to 2 years.

The wind forces are computed using ASCE-7 [13]. CROM's calculation in Appendix A lists a 150 mph wind speed; however, for these tanks a PC2 107 mph wind speed is used. To simplify this calculation and to be conservative, qz = 37 psf will be taken from T-CLC-H-00897 [14], which is for a component on top of a hill (includes hill top affects). The Vault 2 tanks are recessed, but have an open side (to the North).

Fw = wind force = qz(Cf)(G)(A) = (37)(0.5)(0.85)(3300)/1000 = 52 kips

Where: G = Gust factor = 0.85 (wind exposure C)
From Table 6-10, $D^*(qz)^{0.5}$ = (150 ft) $*(37)^{0.5}$ = 912 > 2.5 and h/D = 22/150 = 0.15
$\therefore$ Cf = 0.5 (surface moderately smooth)
A = (22)(150) = 3300 sq ft

Fe = maximum earthquake base shear for wall & roof (without liquid or grout)
= (0.26 from CROM's seismic calc)(wall and roof weight)
= (0.26)(4770 lbs per ft of circumference)(3.14)(Diameter)/1000
= (0.26)(4770 lbs per ft)(3.14)(150 ft)/1000
= 585 kips

Fw < Fe Therefore Seismic controls.

3.10 Discussion of Loads Used to Evaluate Columns (page 11/36 of Reference 1)

Page 11/36 of Reference 1 lists critical axial and moment forces (Pdead = 19.86 kips and Mdead = 13.25 ft-kip) on the column. The column capacity is Pc = 177.14 kips and Mc = 356.655 ft-kips. DOE asked why a higher axial force (due to a larger tributary area – 20' by 20') was not used. CROM's engineer stated that it was because he wanted to check a column with an unequal tributary area. This case, which gives unbalanced moments on the slab, will result in a moment and axial load on the column. Page 21/36 gives a maximum punching shear value of 66.8 kips, Vu2. This value appears to be based on a 20' by 20' tributary area. Based on the above capacities, the column is acceptable.

4.0 Results and Conclusions

4.1 Results

Table 1 - Comparison of Selected CROM Program Output Values with Section 3.0 Results

Selected CROM Program Output Description	CROM Program Results	Alternate Calculation Results
Floor (Bottom Slab)		
Bottom slab thickness at wall	11 in	11 in
Bottom slab thickness away from wall	8 in	8 in
Water + Slab Pressure	1905 psf	
Grout + Slab Pressure		2564 psf
Edge of Slab Weight Pressure	138 psf	138 psf
Shear on Footing edge	3404 lbs	3140 lbs
Shear Stress on Footing Edge	34 psi	23.79 psi
Moment on Footing	4396 ft-lbs/ft	4082 ft-lbs/ft
Required Steel	0.35 in^2 (0.99 in^2 provided)	0.37 in^2 (0.99 in^2 provided)
Wall		
Required wall thickness at top	9.66 in	9 in
Required wall thickness at bottom	14.27 in	14.24 in
Wall weight at bottom slab	5240 lbs	4770 lbs (Section 3.1) 4560 lbs (Section 3.5)
Number of wires required to resist the outward hydraulic force		53.9
Number of wires to resist residual stress		11.79
Total wires	65	65.7
Initial Prestress (Internal Hydro + Backfil)	1326 psi	1341 psi
Final prestress (Internal Hydro)		1114 psi
Final prestess (Backfill)	896 psi	893 psi
Total Prestress	2222 psi	2007 psi
Total Deflection	1.765 in	1.66 in
Wall Base Shear	3668 plf	3339 plf
Moment – Inside Steel	7928 ft-lbs/ft	7217 ft-lbs/ft
Required steel	0.678 in^2 /ft (0.88 in^2 provided)	0.536 in^2 /ft (0.88 in^2 provided)
Moment – Outside steel	9511 ft-lbs/ft	10573 ft-lbs/ft
Required Steel	0.722 in^2 /ft (0.88 in^2 provided)	0.827 in^2 /ft (0.88 in^2 provided)
Bottom Circumferential Rebar (1%)	4.77 in^2 /ft	4.77 in^2 /ft
Top Circumferential Rebar (1%)	2.52 in^2 /ft	2.52 in^2 /ft

4.1 Conclusions

The manual computations of selected computer program output values for the wall in Section 3.0, which are summarized in Table 1, produced results comparable to the results from CROM's proprietary computer program. Therefore, the results from CROM's computer program are considered acceptable.

Also, the computerized results were also validated by CROM's Senior Vice-President and Area Manager using an excel spread sheet. A portion of this excel spread sheet is included in Section 3.1.

The calculations in Reference 1 for the roof slab, columns, bottom slab, settlement, and openings were not verified in this calculation, since these computations used MATHCAD and were previously reviewed and accepted. Also, the seismic computations were not verified, but a qualitative assessment was performed for a fully grouted tank.

Of the four load cases evaluated, Load Case 3 controls (Tank empty, walls prestressed, and soil backfill). From Table 1, the wall compression demand is 2007 psi and the Capacity is 2025 psi. Therefore, the Demand to Capacity (D/C) ratio is 0.99 (2007/2025). For the thermal load case, the As required is 0.827 in2 and the As provided 0.88 in2. Therefore, the D/C = 0.94.

5.0 References

1. Purchase Order No. WB00001K, sheet 6B, 6/29/09, Area Z Saltstone Storage Tanks, Two 2,900,000 – Gallon Saltstone Storage Tanks.

2. IBC, International Building Code

3. T-CLC-Z-00017, Rev A, "Saltstone Vault No. 2 – Structural Performance Assessment".

4. ACI 372R-03, Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures.

5. ACI 350.3-06, "Seismic Design of Liquid-Containing Concrete Structures and Commentary".

6. ACI 318-05, Building Code Requirements for Structural Concrete and Commentary.

7. American Water Works Association (AWWA) Standard D110, 2004, "Wire- and Strand- Wound, Circular, Prestressed Concrete Water Tanks".

8. ACI Committee Report No. 344R-70, Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures". (Per SRS HIS System, this report has been withdrawn.)

9. Timoshenko's Theory of Plates and Shells.

10. T-CLC-G-00261, Rev 0, "Determination of PC1 and Equivalent PC2 Horizontal Design Response Spectra at SRS".

11. DOE/EH-0545, March 1997, "Seismic Evaluation Procedure for Equipment in US DOE Facilities".

12. "Circular Concrete Tanks Without Prestressing", 1993, by Portland Cement Association (PCA).

13. ASCE-7, 2005, "Minimum Design Loads for Buildings and Other Structures".

14. T-CLC-H-00897, Rev 1, "Tank # 38 Purge Fan Stack Extension Design".

Appendix A

Selected Pages from CROM's Calculation

Calculation Continuation Sheet

Calculation No. T-CLC-Z-00022	Rev.	Sheet No.
Evaluation of Selected Values from CROM's Calculation for the Z-Area Saltstone Storage Tanks	0	A2

SuperStop Design

THE CROM CORPORATION
Prestressed Composite Tanks

Job No.: 08084

Project: Two 2.9-MG Saltstone Storage Tanks

3/36

-- INPUT SECTION --

PROJECT DESCRIPTION:	
Floor-wall joint type:	SuperStop
Project name:	Saltstone Storage Tanks
Tank description:	Two 2.9-MG Saltstone Storage Tanks
Engineer / Office:	Bechtel Savannah River, Inc. / Aiken, SC,
Crom job number:	08084
Location of project:	Aiken, South Carolina
TANK DIMENSIONS:	
Inside diameter, ID:	150.000 ft. ← ✓
Sidewall depth, SWD:	22.000 ft. ← ✓
FLOOR DEFINITION:	
Floor thickness, tfl:	8.000 in. ← ✓
Floor concrete specified compressive strength, f'c:	5000 psi ← ✓
Rise in floor at edge:	3 in.
Drop in floor at edge:	0 in.
Distance to floor slope from ID:	1.167 ft.
Length of floor slope at edge:	0.5 ft.
Minimum floor edge flat width beyond ID:	2.580 ft.
SHOTCRETE & WALL REINFORCEMENT:	
Shotcrete specified compressive strength, f'g:	4000 psi ← ✓
Shotcrete modulus of elasticity, Eg:	4500 ksi ← ✓
Specified cover over diaphragm:	2 in.
Specified cover coat thickness:	1 in.
Specified shotcrete thickness between layers:	0.125 in.
Poisson's ratio for shotcrete:	0.15
Allowable stress in mild reinforcement, fs:	18 ksi ← ✓
PRESTRESSING WIRE INPUT:	
Wire gauge, ga:	8
Wire losses in wall:	25 ksi ← ✓
Wire losses in roof:	25.6 ksi
Residual compression:	200 psi
COREWALL PARAMETERS:	
Maximum allowable concrete compression stress:	
From initial prestress:	2500 psi ← ✓
From final prestress:	2200 psi ← ✓
Allowable concrete compression stress factor:	
From initial prestress:	0.55 ← ✓
From final prestress:	0.45 ← ✓
APPLIED LOADS & CONDITIONS:	
Additional head above top of wall:	0.000 ft.
Specific gravity of tank contents:	1.32 ← ✓
Combined thru-wall temperature differential:	100°F ← ✓
Shotcrete modulus of elasticity for temperature, Et:	2000 ksi
Coefficient of thermal expansion, αt:	0.0000065 in./in./°F
SHEAR & MOMENT FACTORS:	
SuperStop friction coefficient:	0.70
GEOTECHNICAL & BACKFILL INPUT:	
Backfill height:	22 ft
Backfill moisture condition:	Wet
Backfill equivalent hydrostatic unit weight:	93.7 pcf ← ✓
Allowable uniform soil bearing pressure:	3.5 ksf

SuperStop Design — THE CROM CORPORATION, Prestressed Composite Tanks — Job No.: 08084

Project: Two 2.9-MG Saltstone Storage Tanks

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— INPUT SECTION —

SEISMIC WITH RESTRAINT CABLES INPUT:		
Seismic code basis:	IBC - International Building Code	
Acceleration at short period, Ss:	0.600 (as fraction of g)	
Acceleration at at 1 sec period, S1:	0.200 (as fraction of g)	
Site class definition:	D	
Importance factor definition:	Cat3	
Seismic cables as single strand or paired strands:	Pair	
Maximum cable spacing:	16 ft.	
WIND INPUT:		
Basic wind speed, V:	150 mph	← ✓
Importance factor, I:	1.15	← ✓
Exposure category:	C	

— OUTPUT SECTION —

TANK SIZE & CAPACITY OUTPUT:		
Inside radius:	75 ft.	← ✓
Tank capacity:	2.908-MG	←
Actual wall height:	21.750 ft.	
FLOOR RESULTS:		
Total floor thickness at edge:	11 in.	← ✓
Floor concrete modulus of elasticity:	3605 ksi	
Typical water plus slab pressure:	1905 psf	✓
Wall weight:	5,240 plf	←
Edge of slab weight pressure:	138 plf	✓
Calculated net pressure:	1,768 plf	←
Calculated bearing width:	2.964 ft.	
Calc'd width - inside face of wall to edge of slab:	2.077 ft.	
Adj'd width - inside face of wall to edge of slab:	2.583 ft.	✓
Width of full flat edge:	3.750 ft.	←
Resulting pressure:	1318 psf	✓
Shear on floor edge:	3.404 klf	←
Shear stress on floor edge:	34 psi < 417 psi, o.k.	← should be 70psi, $1.1\sqrt{f'c}$ -
Bending moment on floor edge:	4.396 kip-ft/ft	
Required floor edge radial reinforcement:	0.348 sq.in./ft.	
Provided floor edge reinforcement w/ double mat:	0.992 sq.in./ft.	
PRESTRESSING WIRE OUTPUT:		
Prestressing wire ultimate strength:	231 ksi	
Prestressing wire initial stress:	145.6 ksi	
Prestressing wire diameter:	0.162 in.	← Given ✓
Prestressing wire area:	0.0206 sq.in.	
Prestressing final stress - wall:	121 ksi	← (146-25) ✓
Prestressing final stress - roof	120 ksi	
Required wires at base of wall:	65	← ✓
MISCELLANEOUS LOADS OUTPUT:		
Unit weight of tank contents:	82.056 pcf	← ✓
Total temperature difference for design:	100°F	
BASIC WALL RESULTS OUTPUT:		
Required corewall thickness at base, tcb:	12.25 in.	
Required corewall thickness at top, tct:	8.5 in.	
Allowable stress from initial prestress w/ overstress:	2475 psi	← ✓
Calculated stress from initial prestress:	1326 psi	← ✓
Calculated stress from backfill:	900 psi	← ✓
Total stress from initial prestress + backfill:	2227 psi	← ✓
Allowable stress from final prestress w/ overstress:	2025 psi	← ✓

SuperStop Design

THE CROM CORPORATION
Prestressed Composite Tanks

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--- OUTPUT SECTION ---

Calculated stress from final prestress:	1099 psi
Total stress from final prestress + backfill:	1099 psi
H2/Dt:	3.089
Lower bound within H^2/Dt tables:	3.0
Upper bound within H^2/Dt tables:	4.0
WALL THICKNESSES OUTPUT:	
Base of wall:	
Maximum number of wire layers:	4
Full covercoat thickness:	2.023
Full wall thickness:	14.273
Full wall thickness including boss:	15.273
Top of wall:	
Number of wire layers:	1
Full covercoat thickness:	1.162
Full wall thickness:	9.662
Full wall thickness including boss:	11.662
Average full wall thickness:	11.968 in.
WALL WEIGHTS OUTPUT:	
Unadjusted wall weight:	3,254 plf
Base of wall boss weight:	38 plf
Top of wall boss weight:	63 plf
Roof band weight:	75 plf
Total wall weight adjusted for bosses & bands:	3,429 plf
Total dome dead weight:	1,812 plf
Dead load surcharge on wall:	0 plf
Total dead load on wall:	5,240 plf
SHEAR & MOMENT PARAMETERS OUTPUT:	
Deflection calculations:	
Circumferential wall stresses:	
Applied stress due to initial prestress:	1326 psi
Applied stress due to backfill:	896 psi
Total applied stress:	2222 psi
Coefficients:	
Average shrinkage, ε:	0.00080 in./in.
Average creep, Ccr:	0.0000003 in./in./psi
Deflections:	
From prestressing & backfill, Δpb:	0.444 in.
From shrinkage, Δs:	0.720 in.
From creep, Δcr:	0.600 in.
Total deflection, ΔT:	1.765 in.
Hinged base shears calculations:	
Supporting data:	
Equiv fluid weight from initial ps & bkfl:	217.104 pcf
Coefficient from shear table:	0.1561
Shears on hinged base:	
From prestressing & backfill, Vpb:	16,034 plf
From shrinkage, Vs:	25,974 plf
From creep, Vcr:	21,646 plf
Total shear, VT:	63,655 plf
Interpolation factors & results:	
Chart plotted defection at 13 kips:	1.404 in.
Total wall design dead load:	5,240 plf
Dead load per bearing pad:	5,240 plf
BearStop calculated shear per pad:	2,682 plf
Total BearStop calculated shear:	2,682 plf
BearStop calculated deflection:	1.690
BearStop calculated coefficient of friction:	0.512

Given

SuperStop Design

THE CROM CORPORATION
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--- OUTPUT SECTION ---

Multiplier based on input friction factor:	1.368	
Resuting design base of wall shear:	3,668 plf	✓
Resulting coefficient of friction:	0.700	

DESIGN SHEAR & MOMENTS:

Shears at base of wall:		
Final coefficient of friction:	0.70	
Final shear at base of wall:	3.668 klf	
Design vertical inside moment:		
Maximum inside bending moment:	7.928 kip-ft/ft	✓
Moment location as % wall height from top:	76%	
Moment location from base of wall:	5.250 ft.	
Design vertical outside moment:		
Temperature coefficient from table:	7.356	
Maximum outside bending moment:	9.511 kip-ft/ft	

MILD STEEL REINFORCEMENT RESULTS:

Inside vertical reinforcement:		
Area of diaphragm per foot of circumference:	0.255 sq.in./ft.	
Corewall thickness at maximum moment:	11.345 in.	
Effective depth:	8.907 in.	
Total area of steel required:	0.678 sq.in./ft.	✓
Area of rebar required:	0.423 sq.in./ft.	
Calculated longest cut-off distance:	15.750 ft.	✓
Calculated shortest cut-off distance:	12.250 ft.	
Outside vertical reinforcement:		
Corewall thickness at maximum moment:	10.375 in.	
Effective depth:	9.938 in.	
Area of rebar required:	0.722 sq.in./ft.	✓
Bar size:	#5	
Calculated spacing:	5.153 in.	
Calculated longest bar length:	29.000 ft.	
Calculated shortest bar length:	27.000 ft.	
Bottom circumferential reinforcement:		
Height of wall encompassing reinforcement:	3 ft.	
Thickness of wall encompassing reinforcement:	13.250 in.	
Area of wall encompassing reinforcement:	477 sq.in./ft.	(3')(13.25") ✓
Area of rebar required:	4.770 sq.in./ft.	1% of WAll Area ✓
Bar size:	#5	
Total number of bottom circumferential bars:	16	
Top circumferential reinforcement:		
Thickness of wall encompassing reinforcement:	10.500 in.	
Area of wall encompassing reinforcement:	252 sq.in./ft.	(2')(10.5") ✓
Area of rebar required:	2.520 sq.in./ft.	1% of Wall Area ✓
Bar size:	#4	
Total number of top circumferential bars:	13	

SEISMIC RESULTS PER IBC & ACI 350.3:

Basic parameters:		
Importance factor, I:	1.50	NOT VERIFIED
Impulsive structure coefficient, R_I:	3.00	
Convective structure coefficient, R_C:	1.00	
Site coeff for short period acceleration, Fa:	1.320	
Site coeff for 1 sec period acceleration, Fv:	2.000	
Total weight of tank wall, W_S:	1616 kip	
Total weight of tank roof, W_R:	854 kip	
Effective mass of tank contents:		
Total weight of tank contents, W_T:	31,901 kip	

Appendix B

Selected References

1. email from Brent Gutierrez to Fred Schultz, dated 8/18/09 (1 page)

2. Pages from SOW, C-SOW-Z-00001, Rev 1 (4 pages)

3. Documentation of a Telecon with Ryan Harvey and Jim Kelley (1 page)

4. "Temperature Moments in Circular Tanks". This table was developed for CROM Corporation by the University of Florida. (1 page)

Calculation Continuation Sheet

Calculation No. T-CLC-Z-00022	Rev.	Sheet No.
Evaluation of Selected Values from CROM's Calculation for the Z-Area Saltstone Storage Tanks	0	B2

Brent Gutierrez/DOE/Srs
08/18/2009 04:45 PM

To Frederick Schultz/DOE/Srs@Srs
cc
bcc
Subject Issues with Technical Review of Saltstone Vaults 2A and 2B Design

Fred:
In our technical review of the Vault 2A & 2B design we cannot explicitly determine the if all of the relevant design loads have been adequately assessed and accounted for in the structural design of the tanks. While we have determined what national consensus codes and standards were used in the design, the structural calculations as we have them do not lend themselves to independent verification and thus we cannot ensure the appropriate design loads have been addressed. Of particular concern are pages 1 through 8 of the CROM calculation provided under WB00001K-006-B-MDM, June 29, 2008. These pages consist only of "input" and "output" information and thus we cannot readily assess if all of the appropriate design load cases have been addressed as required by the applicable national consensus codes and standards and those load cases applicable due the construction and operation sequence as identified in the WSP-SSF-2005-00023, Revision 2, Section 4.18, page 22 of 37. This design load (Section 4.17) may be the controlling loading for the tank design, which is contrary to the assumption made on page 33 of 37 of that same document (first line of the second paragraph of the Executive Summary). Therefore, to complete our technical review of the tank design, we need to be provided with a copy(ies) of the calculational document CROM used that resulted in the "output" sections of pages 1 though 8 of WB00001K-006-B-MDM, June 29, 2008. It is preferable to have a readable/searchable, electronic copy that is not password protected in any manner to facilitate our review.

Let me know if you need more or clarification .... Thanks!

Brent J. Gutierrez, PhD, PE, CEM
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2.3 SRS Documents

2.3.1 Documents

None

3.0 WORK REQUIREMENTS

3.1 Task #1: Tank Design

3.1.1 Tank is required to contain the saltstone grout, without leakage, during the saltstone grout fill operation stages and after the saltstone grout has solidified. (See Attachments 5.3 through 5.8)

3.1.2 Design Parameters

3.1.2.1 Nominal Size: 150 feet inside diameter (fixed) by 22 feet high (minimum inside height at top of wall) for a total capacity of 2.9 million gallons per tank

3.1.2.2 Minimum Design Life:

A. Operating: 10 years with a water tight seal

B. Structural: 25 years

3.1.2.3 Design, construction, examination and testing in accordance with one of the following: AWWA D110 or AWWA D115.

A. Use of AWWA D110 is limited to concrete panels incorporated into structure as follows:

1. Type I, Cast-in-place concrete with vertical pre-stressed reinforcement
2. Type III, Pre-cast concrete without steel diaphragm but with vertical pre-stressed reinforcement

B. Foundation – Cast-in-place concrete

C. Walls

1. Cast-in-place or pre-cast concrete
2. Pre-stressed or post-tensioned in the circumferential direction
   a. Additional vertical tensioning is acceptable.

D. Roof – Cast-in-place or pre-cast concrete

1. Pre-stressing or post-tensioning may be used.

3.1.2.4 Special Design Conditions

A. Lateral forces will be present due to the empty tank being buried to the roof line using dynamic compaction equipment.

1. Prepare Specifications for Back Filling.

B. The tank will not be filled with water for purposes of leak testing or backfill.

1. Do not consider sloshing.
2. Do not provide drainage for the tank.
3. Do not provide a leachate collection system.

C. Filling of the tank with liquid saltstone grout will be done with incremental lifts over a period of several months. For design purposes, each incremental lift will not exceed 12 inches. Individual lifts will undergo initial curing prior to placement of the next lift.

3.1.2.5 Tank top – capable of supporting 30 pounds per square foot live load and the equipment loads in accordance with Attachment 5.7.

3.1.2.6 Design roof interior columns and any required intermediate supports with structural pipes to minimize obstruction / resistance to saltstone grout flow to perimeter walls.

3.1.2.7 Minimum thickness of concrete components:

A. Foundation Slab: 12 inches with a minimum of 3 inch cover for reinforcing steel (top / inside face)

B. Walls: 8 inches with a minimum 3 inch cover of reinforcing steel (inside face)

C. Roof: 8 inches

3.1.2.8 Design the roof assembly of each tank in accordance with Attachment 5.7 including:

A. Penetration sleeves

B. Embed plates, including supported loads

C. Penetration covers and plugs

3.1.2.9 To allow membrane installation by Others at later date:

A. Provide the tank exterior surfaces with a smooth finish (sides and top)

B. Reinforcing ribs and projections on exterior walls of the tank are not permitted

C. Post tensioning buttresses are permitted

3.1.2.10 Saltstone Grout Material Characteristics:

A. Weight of grout while fluid: 110 pounds per cubic foot

B. Temperature Range during placement (based on heat of hydration during curing): 50°F to 195°F

3.1.2.11 Soil Properties

A. Average groundwater table elevation is 225 feet mean sea level with seasonal fluctuation of ± 5 feet.

B. Wet density of the backfill is 125 pounds per cubic foot.

C. Lateral earth pressure coefficients for the backfill are:

1. Active earth pressure coefficient, Ka = 0.33
2. Passive earth pressure coefficient, Kp = 3.0
3. At-rest earth pressure coefficient, Ko = 0.5

D. Allowable soil bearing pressure: 3500 pounds per square foot at elevation 268 feet.

E. Subgrade modulus, in pci (pounds per square inch per inch of deformation)

1. 10 to 20 for a 150 foot diameter foundation
2. 100 to 130 for a 30 inch diameter plate

3.1.3 Structural Requirements:

3.1.3.1 Design for seismic loads in combination with other concurrent service and environmental loads in accordance with ICC IBC, Chapter 16, "Structural Design" and ASCE 7-02 using the following parameters:

A. S_S, 0.2 sec spectral response acceleration = 0.6g

B. S_1, 1.0 sec spectral response acceleration = 0.2g

C. Site Class for SRS (Seismic Design Category) : D

D. Importance factor I_P = 1.5

E. Service loads concurrent with seismic loads shall include operating temperature and pressure.

F. Design to prevent damage to the structure from a seismic event. The associated tank equipment (by others) does not need to function during or after the seismic event.

3.1.3.2 Design tank to withstand the full hydrostatic head of water without leaks in the unburied condition.

3.1.3.3 Construction Loads

A. Design empty tank to withstand backfill static and dynamic loads during backfilling.

B. Design components and lifting lugs for hoisting into position.

C. Design of lifting lugs to consider post-installation surface condition to allow for exterior liner installation.

3.1.4 Service Conditions

3.1.4.1 Environmental Conditions

A. Operational Environment Conditions (i.e. while Tank is being filled):
   1. Pressure: Atmospheric plus hydrostatic head
   2. Temperature:
      a. Minimum: 50°F (10°C)
      b. Maximum: 195°F (90°C) (at the center of the tank)
   3. Relative Humidity: 20% to 100% (Condensing)

B. Ambient Outdoor Environmental Conditions
   1. Temperature:
      a. Minimum: 20°F (-6°C)
      b. Maximum: 110°F (40°C)
   2. Relative Humidity range: 5% to 100% (Condensing)

3.1.5 Design Submittals

3.1.5.1 Submit a Design Package including the following, as a minimum

A. Drawings Index Sheet with project title and list of drawings.

B. General Arrangement Drawing: Includes layout and dimensions including roof openings.

C. Structural Drawings: Provide drawings for tank structure (complete tank).

D. Structural Design Calculations:
   1. Provide supporting calculations including any internal roof supports
   2. Load cases to include:
      a. Dead loads, live loads, and seismic loads
      b. Construction loads
      c. Operating loads during the filling of tank with saltstone grout

10.2.2 Drawings

A. Prepare drawings using Intergraph Microstation version SE (or later – version J preferred) or Autocad Version 14 (or later).
   1. Where electronic media is required for design submittals, provide in Microstation or Autocad format.
   2. Confirm electronic media and files are virus free.
   3. Identify on label of electronic media – Virus application used and the date of virus definition update used.

B. Drawing and lettering shall be of such size and density that, after reduction to half scale, information is clearly legible.

C. Drawings, including reproducibles, electronic media, and prints will become the property of WSRC.

D. The Reference Drawing block on each drawing shall list drawings referenced on that sheet plus the Index Sheet drawing (at a minimum).

3.10.2.3 Calculations

A. Combine calculations in a Design Manual which includes a Table of Contents.

B. Prepare calculations in sufficient detail to ensure that allowable criteria and proper factors of safety have been followed. Provide each calculation with a statement of its problem, the codes and standards governing its design, and a conclusion. Evaluate accepted calculations and revise accordingly to reflect as-built configurations.

C. Provide sufficient detail to allow an individual competent in that discipline to understand the methodology, inputs and results without discussion with originator.

D. For any calculations performed using software, provide copies of the database and/or calculation on CD ROM or equivalent. Include source Mathcad files, if used.

3.10.2.4 Specifications

A. Provide specifications in sufficient detail for the performance of all the construction tasks for tank construction.

B. Prepare in a commercially accepted format (e.g., CSI) to provide well defined activities for the completion of all the construction tasks, unless noted otherwise.

C. Specifications should be divided in sections by types of construction activities.

D. Include construction tolerances.

3.10.3 Inspection / Testing Laboratory Reports

3.10.3.1 Develop and complete written reports, of required testing and inspections specified within this specification, and include the following, at a minimum:

A. Date issued

B. Project title and Specification number

C. Name of inspector or laboratory technician

D. Date, time and location of inspection or testing

E. Identification of product, type of activity performed and applicable code or standard used

Jamesp Kelley /WSRC/Srs
01/31/2008 04:09 PM

To Wade Faires/WSRC/Srs@Srs
cc
bcc
Subject Tele-com with Crom

Wade,

I spoke with Ryan Harvey of the Crom Corporation today about the 2.9 million gallon Salt Tank Design calculation summary.

Specifically I had the following questions:

1. How does the design account for crack control in the 150 foot diameter monolithically poured concrete roof? Ryan answered the design uses enough reinforcing such that any cracking would be hair line at best. The Crom Corp. has recently poured a 280 foot diameter concrete roof monolithically and did not have any concerns with cracking.

2. A 100 degree F differential temperature was used in the design of the tank. If this delta T increased to 150 degrees some yielding of pretensioned wires could occur and some micro cracking could be formed however this would be self limiting and would not jeopardize the integrity of the tank walls. Furthermore the calculation uses 18 ksi steel in its design when in reality 60 ksi steel would be used during construction. Therefore there is a 60/18 = 3.33 factor of safety built into the initial design. Any change in the delta T should not affect the wall design.

3. Did Crom consider a seismic load case where the tank was empty with earth pressure against the tank wall? The calculation summary I reviewed did not specify this load case. Ryan replied that load case was considered in the design but was not specifically mentioned since it was not the governing seismic load case.

4. I asked about the use if a 1.8 Specific Gravity on the Base Mat deign. Ryan answered that the base mat would transfer any loads directly to the underlying soils and that the 1.8 Specific Gravity does not affect the design of the base mat.

5. I asked about differential settlement issues in the design. Ryan stated their design is based on ACI 372 and that the tank design accounts for a differential settlement of Dia. x 12 /300. He was not given an opportunity to review the soils reports (specifically omitted from his scope of work), but did say that differential settlement should not be a concern.

6. I asked about the qualification of the interior columns since his calculation summary did not specifically mention this. Ryan stated the design of the columns (both static and seismic load cases) were covered in the previous calculation summary and there was no change from the previous submittal.

In summary, I have no outstanding concerns for the design of this tank from Crom. If you have any questions please contact me at 2-9720.

Jim Kelley

TEMPERATURE MOMENTS IN CIRCULAR TANKS

Moment = Temp. Coef. x T_c x E x t^2 x $(T_i - T_o)$

E' = Modulus of Elasticity of Shotcrete = 2,000,000 psi*
T_c = Coef. of Thermal Expansion = 0.0000065"/"/°F
t = Thickness of Wall at Midheight, in feet
T_i = Temperature of Inside Wall Face, °F
T_o = Temperature of Outside Wall Face, °F

MAXIMUM TEMPERATURE COEFFICIENTS FOR MIDHEIGHT

H^2/DT	Coef.	H^2/DT	Coef.
0.40	0.236	14.00	12.941
0.80	0.902	16.00	12.804
1.20	1.891	18.00	12.656
1.60	3.068	20.00	12.516
2.00	4.309	24.00	12.288
3.00	7.165	28.00	12.135
4.00	9.299	32.00	12.041
5.00	10.744	36.00	11.989
6.00	11.685	40.00	11.964
8.00	12.656	44.00	11.956
10.00	12.987	48.00	11.956
12.00	13.029	56.00	11.967

These coefficients are for a material which is:

1. Isoelastic, homogeneous, linear stress-strain characteristics.
2. Time independent.
3. Temperature changes are axisymmetric.
4. Shell walls are uncracked and of constant thickness.

* E', Modulus of Elasticity - because shotcrete meets none of the above four "material" criteria, it is customary to use a more realistic value of "E'" for Temperature computations.