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				using ANSYS Slice				
				Parametric Model for Tank				
				SST-BX				

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To	From	Page 1 of 1
Distribution	Design Engineering	Date 6/17/03
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Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX

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Abstract: This document documents the ANSYS slice parametric model for single-shell tank BX and provides sample calculation for analysis-of-record mechanical load conditions.

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Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX

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JLR The Engineering Solutions Company

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Revision 0

Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington
Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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The subject document has been reviewed by the undersigned.
The reviewer reviewed and verified the following items as applicable.

Document Reviewed: RPP-13999, Rev. 0, Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX

Analysis performed by: Xianghong Li / Jim Radochia
JLR The Engineering Solutions Company

- Design Input*
- Basic Assumption
- Approach/Design Methodology
- Related Information
- Conclusion/Result Interpretation

*Default values of changeable parameters in model are for example only. User of model must confirm proper input of parameter values for specific application of model.

An electronic version of model is available from undersigned. See attached ERATA sheet for any known problems with model.

Reviewer/Approver (print) L. J. Julyk / Design Engineering

Reviewer/Approver (signature) 6/17/03
Date

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed: RPP-13998, Rev. 0, Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX

Author: Xianghong Li / Jim Radochia
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Yes	No	N/A	
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors.
[X]	[ ]	[ ]	Code run streams correct and consistent with analysis documentation.
[X]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[ ]	[ ]	[X]*	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[ ]	[ ]	[X]*	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.

* Sample Calculation / Model Development

B. V. Winkel (M&D) B V Winkel 6-10-03
Reviewer Date

L. J. Julyk (CHG) Julyk 6/17/03
Reviewer Date

ERRATA

ANSYS Macro	Tracking #	Issue Description	Recommended Action
Parm_bx.mac	1	Material properties are set at default values that may or may not be appropriate for specific analysis.	Verify material input values appropriate for specific analysis.
Parm_bx.mac and Sst_bx_slice.mac (see set material properties)	2	Concrete creep coefficients listed are incorrectly specified for implicit user-defined creep. Solid65 elements can only use explicit creep. Error is in report listing only; actual macro files are correct.	See RPP-13990 for proper creep coefficient specification and usage.

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ANALYTICAL CALCULATIONS

		Page	1 of 75
Subject	**Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-BX**		
Originator	Xianghong Li	Date	4/23/03
Checker	Jim Radochia	Date	4/23/03

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1.0 OBJECTIVE/PURPOSE

The purpose of this calculation is to develop a parametric model for the single shell tank (SST) BX, and provide a sample analysis of the SST-BX tank based on analysis of record (AOR) loads. The SST-BX model is based on buyer-supplied as-built drawings and information for the AOR for SSTs, encompassing the existing tank load conditions, and evaluates stresses and deformations throughout the tank and surrounding soil mass.

These sample calculations in this document are not to be used for assessing the structural integrity of the SST-BX tanks at the Hanford site.

2.0 METHODS OF ANALYSIS

1. A 3-degree slice 3D model of the SST-BX tanks was first developed using the ANSYS Parametric Design Language (APDL) in ANSYS 7.0, a general purpose finite element analysis program [Ref 1]. The 3D slice model includes some non-linear characteristics of the analysis such as a) contact between the soil and tank with friction and b) plastic soil material. Also, the reinforcement bars embedded in the concrete tank were included for this analysis.

2. The parametric model of the SST-BX tank was then analyzed based on AOR loads. Contour plots showing stress and displacement are provided, as well as path plots showing section force/moment.

3.0 INPUT DATA

The geometry of the SST-BX tank is provided in drawing H-2-602 [Ref 4], and is shown in Figure 1. The parametric model includes material properties for the tank and nominal soil material properties. For purposes of this calculation, the soil overburden (at the top of the tank dome) is 8.83 feet [Ref 3], with a unit weight of 125 pcf and Poisson ratio of 0.27. The soil is divided into three layers as shown in Figure 2. Each layer has a different elastic modulus. Material properties for structural concrete and soil are the same as those in document RPP-14249 [Ref 2]. The concrete reinforcing bar properties are also specified. All linear material properties are listed in Table 1.

Table 1. Linear Material Properties

Material	Elastic Modulus (ksi)	Poisson's Ratio	Density (lb/ft³)
Structural Concrete	3,100	0.2	150
Top Soil *	7	0.27	125
Mid-Soil*	13	0.27	125
Bottom Soil*	20	0.27	125
Tank Rebar Steel	27,700	0.3	490
Slab Rebar Steel	27,700	0.3	490

*Drucker-Prager plasticity is used for soil, and the friction angle is 35.4 degrees for all three layers of soil.

The concrete tank is modeled with 3D solid elements SOLID65, and the soil is modeled with SOLID45 elements. Figures 3 through 5 show the finite element mesh used for this calculation. The tank is divided into small volumes of 1" wide according to the location of the steel reinforcing bars (Figures 6 to 8). Real constants are assigned to tank elements to represent the rebar volume ratios and rebar orientations (Figure 9). The volume ratio is calculated using Excel spreadsheets listed in Tables 2 to 5. In the dome and slab, the volume ratio of the radial rebars increases linearly with decreasing radius. Given this variety of rebar volume ratio, the average radius was used during the calculation of the real constants for the meridional rebars in the dome and slab. There are 3 element coordinate systems used to orient the rebars, and they are listed in Table 6. Figure 10 shows the rebar elements colored by element coordinate systems. Figure 11 to 13 depict the rebar orientations at various locations of the concrete tank. Standard contact with a friction coefficient of 0.3 is defined between the tank and the surrounding soil.

The AOR loads for the SST-BX tank include a uniform pressure load of 40 lbf/ft² on the soil surface and a concentrated load of 200 kips over a circular region with a radius of 10 ft. The concentrated load is applied to the soil surface as a uniform pressure load in this calculation. A vacuum load of -6 in. water gage is also applied to the inside surface of the tank. Boundary conditions are applied to the model so that both ends of the slice are constrained in the circumferential direction, the outside radius surface of the soil is fixed in the radial direction, and the bottom surface of the soil is fixed in the vertical direction. Gravity is also included in the calculation.

The parametric inputs used in this calculation are summarized in the attachments. The files and their functions are listed in Table 7.

Table 2. Calculation of Steel Reinforcement Ratios for Slab

SST-BX - Steel Reinforcement Ratios for Slab - Ref H-2-605													100
Description			Bottom / Meridional				Bottom/ Circumferential				Real
	Elevation (in)	Radius (in)	Size	Spacing	Area Ratio	Volume Ratio	Size	Spacing	Area Ratio	/olume Rati	Constant
Slab Center		0.0									
			4	12.0	0.0164	0.0164	4	12	0.0164	0.0164	100
Start of fillet		404.9									
			6	8.0	0.0552	0.0552	0	0	0.0000	0.0000	101
Start of 1" bar		443.5									
			6	8.0	0.0552	0.0552	8	8	0.0982	0.0982	102
End of rebar		482.5									
SST-BX - Steel Reinforcement Ratios for Slab - Ref H-2-605													100
Description			Top / Meridional				Top/ Circumferential				Real
	Elevation (in)	Radius (in)	Size	Spacing (in)	Area Ratio	Volume Ratio	Size	Spacing (in)	Area Ratio	/olume Rati	Constant
Start of 1" bar		443.5									
			4	24.0	0.0082	0.0082	8	8	0.0982	0.0982	103
End of rebar		482.5									
SST-BX - Steel Reinforcement Ratios for Slab - Ref H-2-605													100
Description			Side-Exterior/ Vertical				Side-Exterior/ Circumferential				Real
	Elevation (in)	Radius (in)	Size	Spacing (in)	Area Ratio	Volume Ratio	Size	Spacing (in)	Area Ratio	/olume Rati	Constant
Top of vertical bar	-7.8										
			6	8.0	0.0552	0.0634	8	6.5	0.1208	0.1208	104
			4	24.0	0.0082						
Bot. of vertical bar	-20.3										
SST-BX - Steel Reinforcement Ratios for Slab - Ref H-2-605													100
Description			Side-Middle/ Vertical				Side-Middle/ Circumferential				Real
	Elevation (in)	Radius (in)	Size	Spacing (in)	Area Ratio	Volume Ratio	Size	Spacing (in)	Area Ratio	/olume Rati	Constant
Slab Top	0.0										
			6	12.0	0.0368	0.0368	7	27.5	0.0219	0.0219	105
Top of vertical bar	-7.8										
			6	12.0	0.0368	0.0368	8	6.5	0.1208	0.1208	106
Bot. of vertical bar	-20.3										
SST-BX - Steel Reinforcement Ratios for Slab - Ref H-2-605													100
Description			Side-Interior/ Vertical				Side-Interior/ Circumferential				Real
	Elevation (in)	Radius (in)	Size	Spacing (in)	Area Ratio	Volume Ratio	Size	Spacing (in)	Area Ratio	/olume Rati	Constant
Slab Top	0.0										
			6	12.0	0.0368	0.0368	7	27.5	0.0219	0.0219	105
Top of vertical bar	-7.8										
			6	12.0	0.0368	0.0368	8	6.5	0.1208	0.1208	106
Bot. of vertical bar	-20.3										

Table 3. Calculation of Steel Reinforcement Ratios for Wall

SST-BX - Steel Reinforcement Ratios for Wall - Ref H-2-605 200

Description	Elevation (in)	Radius (in)	Interior(layer 1) / Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	Interior layer 1 / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Tangent Line	200.3										
			6	12.0	0.0368	0.0368	7	6.0	0.1002	0.1002	201
	180.0										
			6	12.0	0.0368	0.0368	7	10.0	0.0601	0.0601	202
	120.0										
			6	12.0	0.0368	0.0368	7	8.0	0.0752	0.0752	203
	64.0										
			6	12.0	0.0368	0.0368	7	6.0	0.1002	0.1002	204
	16.0										
			6	12.0	0.0368	0.0368	7	10.0	0.0601	0.0601	205
	6.0										
			6	12.0	0.0368	0.0368	7	27.5	0.0219	0.0219	206
Top of Slab	0.0										

SST-BX - Steel Reinforcement Ratios for Wall - Ref H-2-605 200

Description	Elevation (in)	Radius (in)	Exterior(layer 4) / Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	Exterior (layer 4) / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Tangent Line	200.3										
			6	12.0	0.0368	0.0368	7	6.0	0.1002	0.1002	201
	180.0										
			6	12.0	0.0368	0.0368	7	10.0	0.0601	0.0601	202
	120.0										
			6	12.0	0.0368	0.0368	7	8.0	0.0752	0.0752	203
	64.0										
			6	12.0	0.0368	0.0368	7	6.0	0.1002	0.1002	204
	16.0										
			6	12.0	0.0368	0.0368	7	10.0	0.0601	0.0601	205
	6.0										
			6	12.0	0.0368	0.0368	7	27.5	0.0219	0.0219	206
Top of Slab	0.0										

Table 4. Calculation of Steel Reinforcement Ratios for Dome and Haunch

SST-BX - Steel Reinforcement Ratios for Dome and Haunch - Ref H-2-606 300

Description	Elevation (in)	Radius (in)	External / Radial Size	Spacing (in)	Area Ratio	Volume Ratio	External / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Center		0.0									
			6	12.0	0.0368	0.0368	6	12.0	0.0368	0.0368	300
Mid of lap		75.0									
			6	10.7	0.0412	0.0412	6	12.0	0.0368	0.0368	301
		120.0									
			6	19.8	0.0223	0.0446	6	12.0	0.0368	0.0368	302
			6	19.8	0.0223						
		240.0									
			6	33.0	0.0134	0.0535	6	12.0	0.0368	0.0368	303
			6	33.0	0.0134						
			6	16.5	0.0268						
		360.0									
			6	41.0	0.0108	0.0431	8	12.0	0.0654	0.0654	304
			6	41.0	0.0108						
			6	20.5	0.0216						
		384.0									
			6	44.3	0.0100	0.0798	8	8.0	0.0982	0.0982	305
			6	44.3	0.0100						
			6	22.2	0.0199						
			6	11.1	0.0399						
Dome/Haunch core Joint		421.0									
			6	48.5	0.0091	0.0729	10	6.1	0.2062	0.2062	306
			6	48.5	0.0091						
			6	24.2	0.0182						
			6	12.1	0.0364						
end of dome radial bar	252.7	460.0									
			6	6.0	0.0736	0.0736	10	5.0	0.2534	0.2534	307
Haunch Tangent line	220.3										

SST-BX - Steel Reinforcement Ratios for Dome and Haunch - Ref H-2-606 300

Description	Elevation (in)	Radius (in)	Internal / Radial Size	Spacing (in)	Area Ratio	Volume Ratio	Internal / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Center		0.0									
			6	12.0	0.0368	0.0368	6	12.0	0.0368	0.0368	300
Mid of lap		75.0									
			6	10.7	0.0412	0.0412	6	12.0	0.0368	0.0368	301
		120.0									
			6	19.8	0.0223	0.0446	6	12.0	0.0368	0.0368	302
			6	19.8	0.0223						
		240.0									
			6	33.0	0.0134	0.0535	6	12.0	0.0368	0.0368	303
			6	33.0	0.0134						
			6	16.5	0.0268						
		360.0									
			6	41.0	0.0108	0.0431	8	12.0	0.0654	0.0654	304
			6	41.0	0.0108						
			6	20.5	0.0216						
		384.0									
			6	44.3	0.0100	0.0798	8	8.0	0.0982	0.0982	305
			6	44.3	0.0100						
			6	22.2	0.0199						
			6	11.1	0.0399						
Dome/Haunch core Joint		421.0									
			6	48.5	0.0091	0.0729	10	8.0	0.1590	0.1590	308
			6	48.5	0.0091						
			6	24.2	0.0182						
			6	12.1	0.0364						
Haunch Tangent line	220.3										

Table 5. Calculation of Steel Reinforcement Ratios for Haunch Core

SST-BX - Steel Reinforcement Ratios for Haunch Interior - Ref H-2-606 500

Description	Circumferential					Diagonal Ties					Vertiel Ties				
	Size	Quantity	Bar area (in^2)	Area (in^2)	Volume Ratio	Size	Quantity	Bar area	Area (in^2)	Volume Ratio	Size	Bar area	Area (in^2)	Volume Ratio	real constant
Haunch Core															
	10	36	45.60	1425.7	0.0320	5	7	2.15	1624.8	0.0013	10	1.27	144.0	0.0088	500
	10	36	45.60	1425.7	0.0320	5	7	2.15	1624.8	0.0013	10	1.27	144.0	0.0088	501

Table 6. Element Coordinate Systems

CS Number	System Type	Element Axes			Covered Region
		x	y	z	
100	Spheroidal	Thickness Direction	Radial Direction	Hoop Direction	Interior rebars in dome and haunch, haunch core
101	Spheroidal	Thickness Direction	Radial Direction	Hoop Direction	Exterior rebars in dome and haunch
110	Cylindrical	Radial Direction	Hoop Direction	Vertical Direction	Rebars in wall and slab, vertical part of the exterior haunch rebar

Table 7. Input File List

Input File Name	Function	Calling For
sst_bx_slice.mac	Main input creating parametric slice model for SST-BX tank and getting solutions	parm_bx.mac bx_load_slice.mac
parm_bx.mac	Set all parametric variables used to create the parametric model	NONE
slice_load_bx.mac	Apply boundary conditions and AOR loads	NONE
pst_bx_slice.mac	Calculate section forces/moments and generate path plots, output path data to path_bx.dat file	get_res_slice.mac get_hpfrc.mac plpng.mac path_bx.plt axial_path.mac shear_path.mac hoop_path.mac moment_path.mac smisc_plt.plt
get_res_slice.mac	Calculate total forces and moments at individual cross section	NONE
get_hpfrc.mac	Calculate hoop force from hoop stress results	NONE
plpng.mac	Create image hard copy in png format	NONE
path_bx.plt	View setting for path plot	NONE
axial_path.mac	Define and plot the path plot of axial force	NONE
shear_path.mac	Define and plot the path plot of shear force	NONE
hoop_path.mac	Define and plot the path plot of hoop force	NONE
moment_path.mac	Define and plot the path plot of moment	NONE
smisc_plt.plt	Define view settings for rebar stress plots	NONE

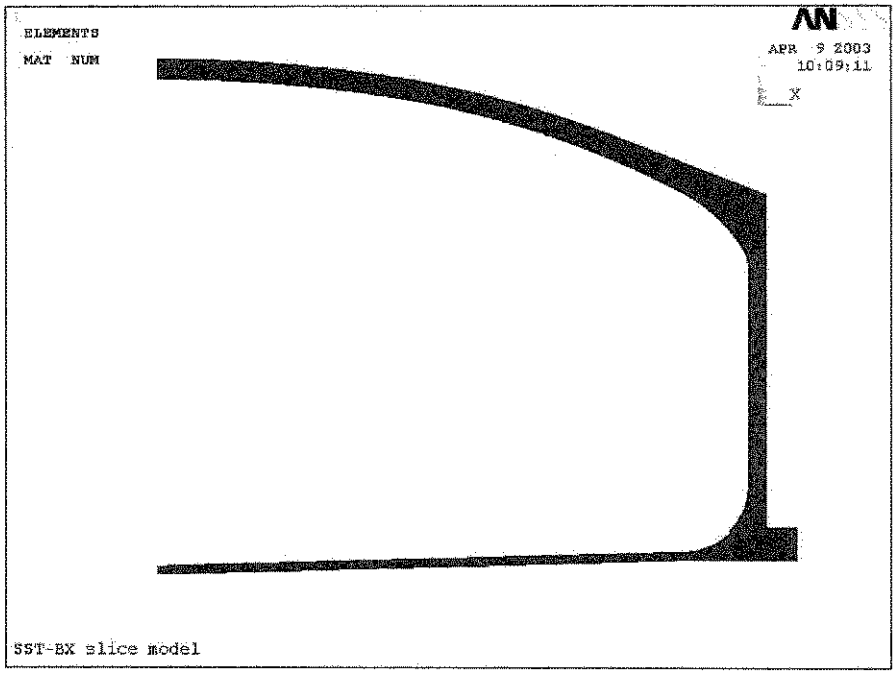

Figure 1. Geometry of SST-BX Tank

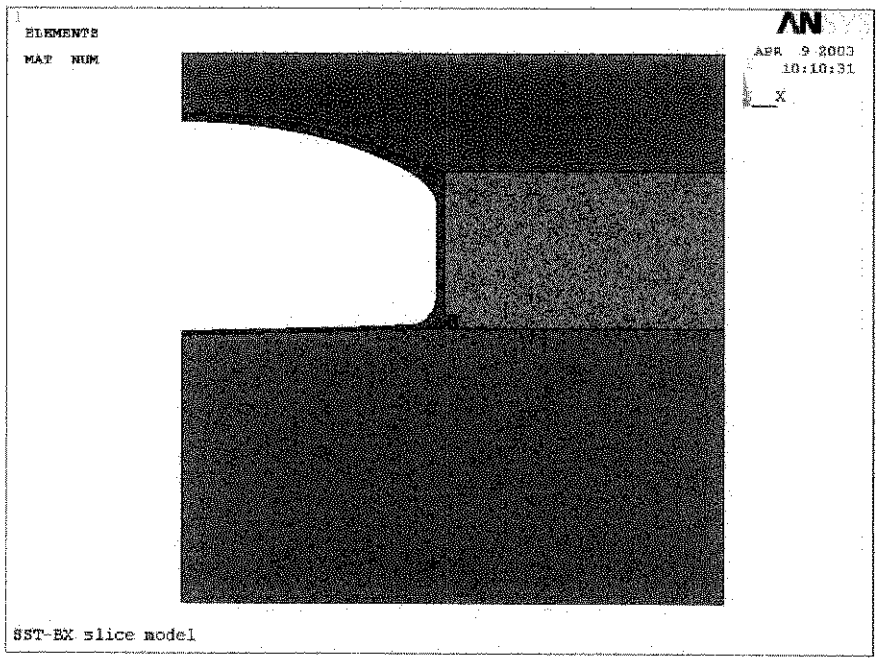

Figure 2. Soil Layers

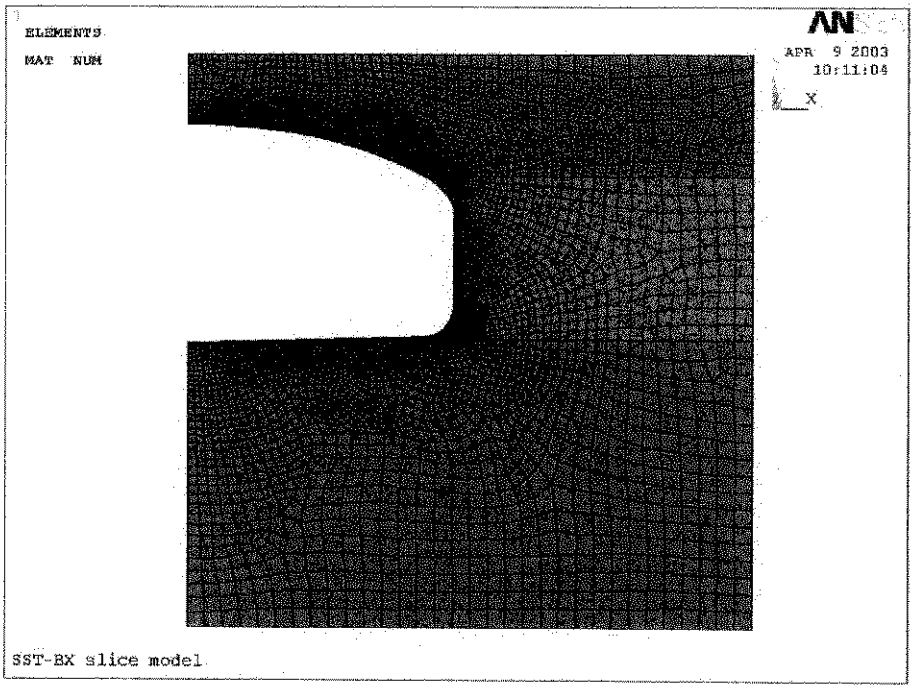

Figure 3. Finite element mesh, showing elements colored by material ID.

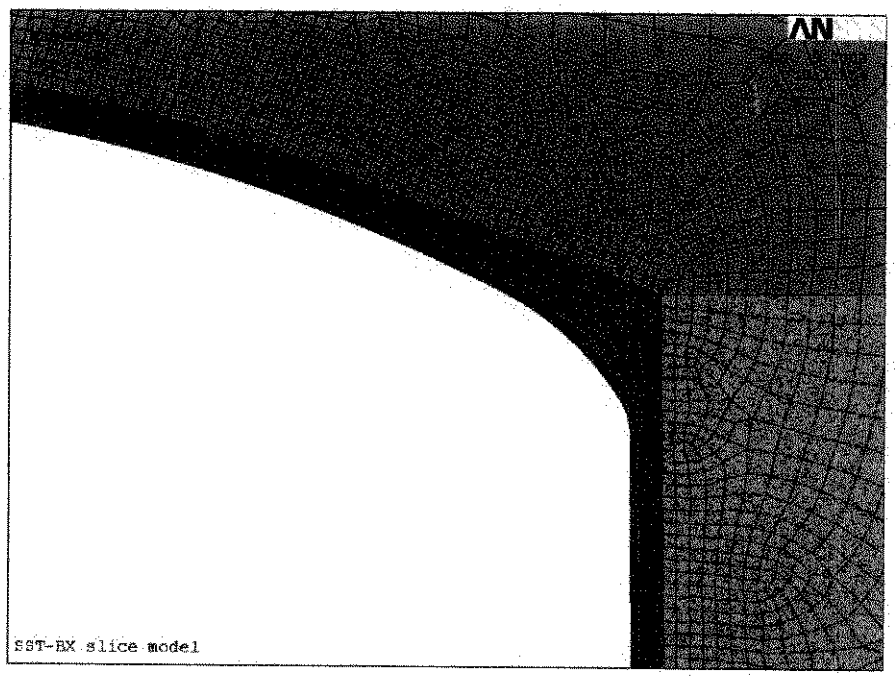

Figure 4. Close-up of finite element mesh.

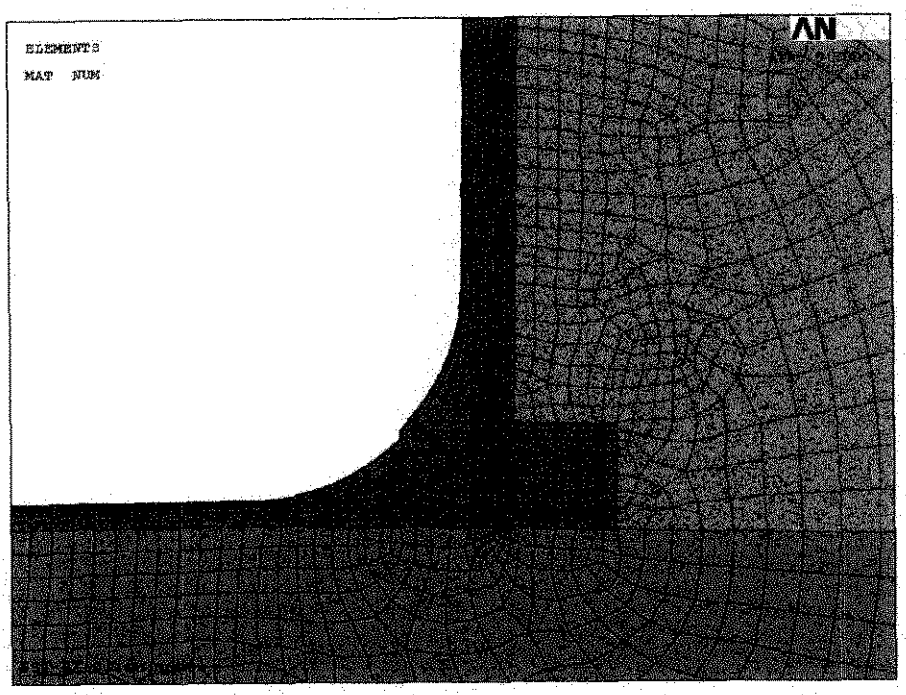

Figure 5. Close-up of finite element mesh.

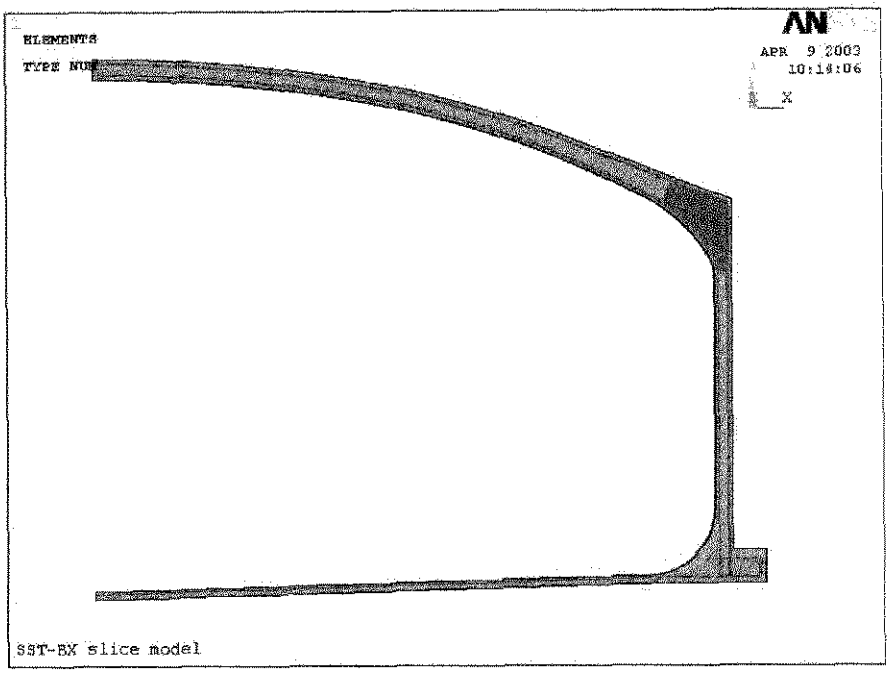

Figure 6. Rebar region (blue colored area)

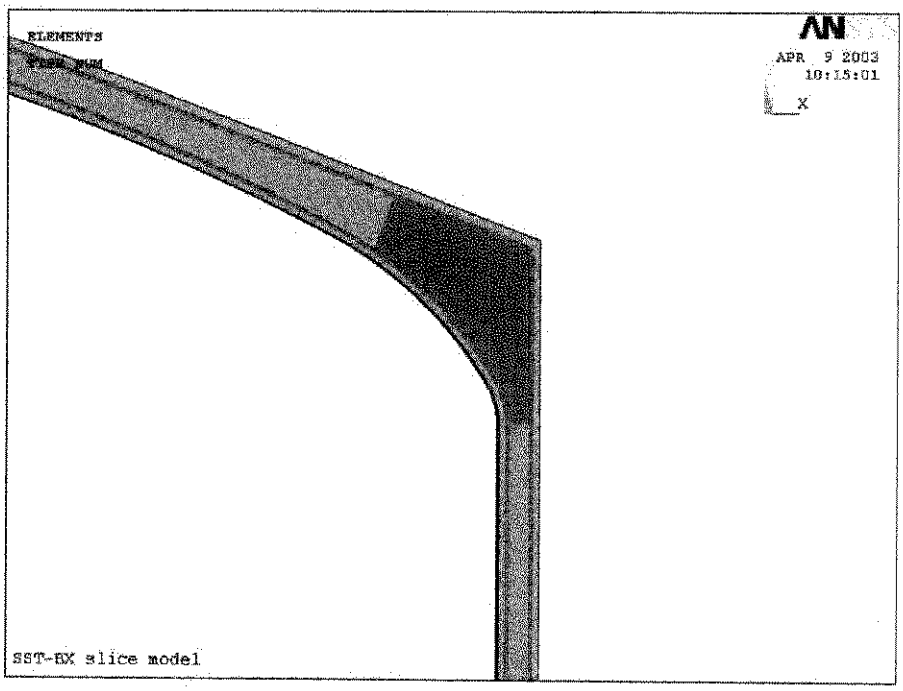

Figure 7. Close up of rebar region

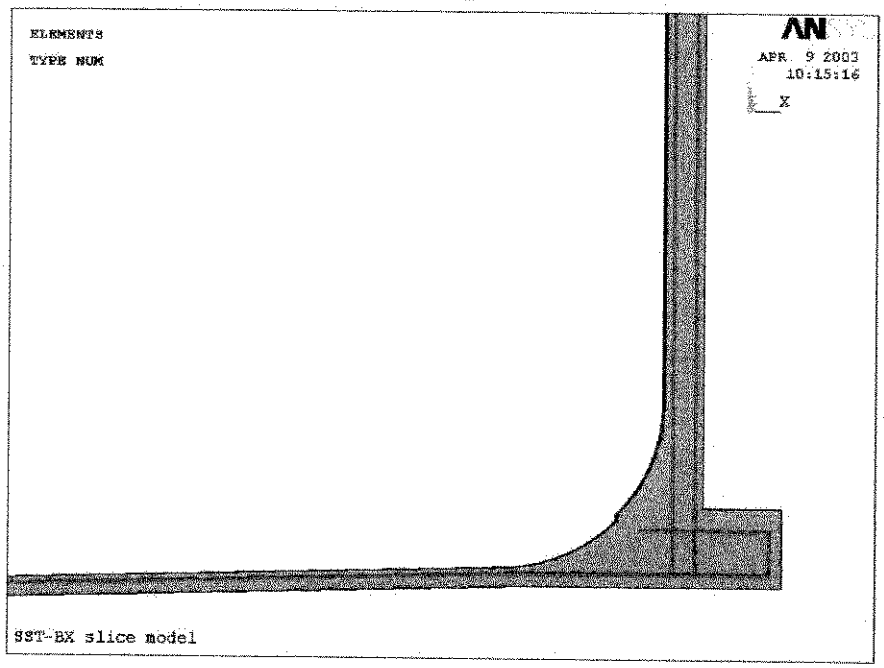

Figure 8. Close up of rebar region

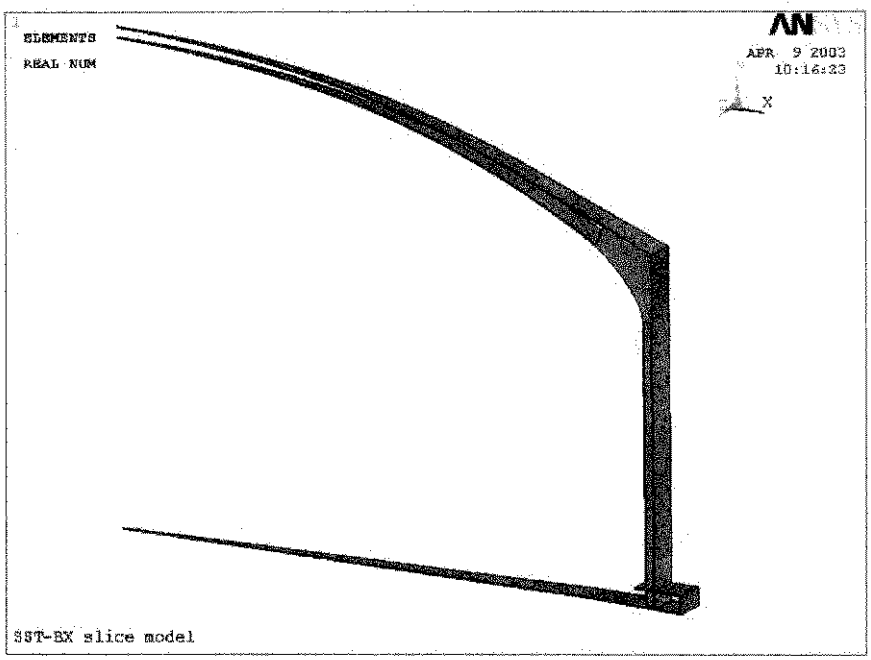

Figure 9. Rebar elements colored by real constants

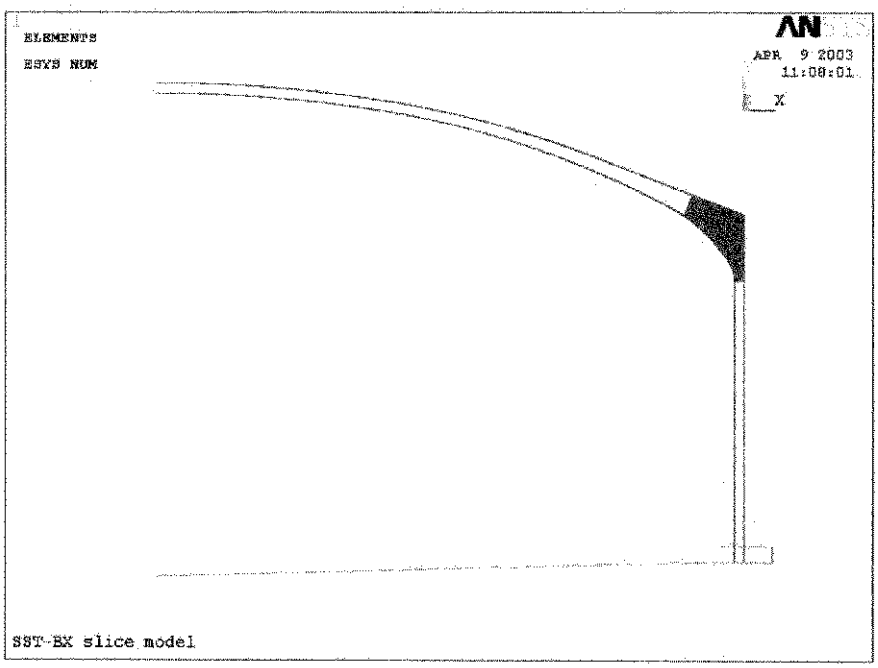

Figure 10. Rebar elements colored by element coordinate systems

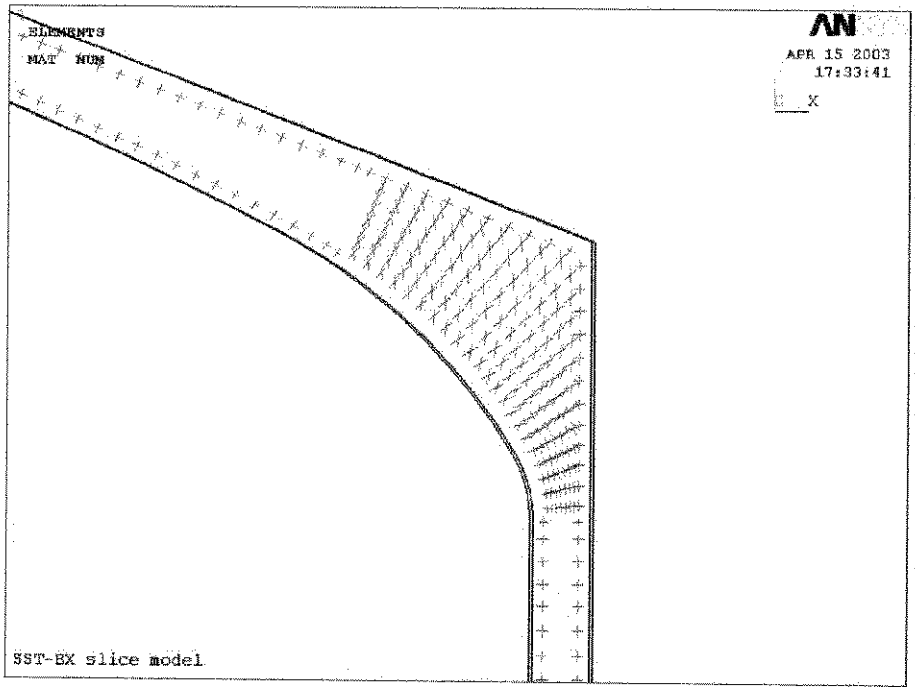

Figure 11. Rebar orientation at haunch core

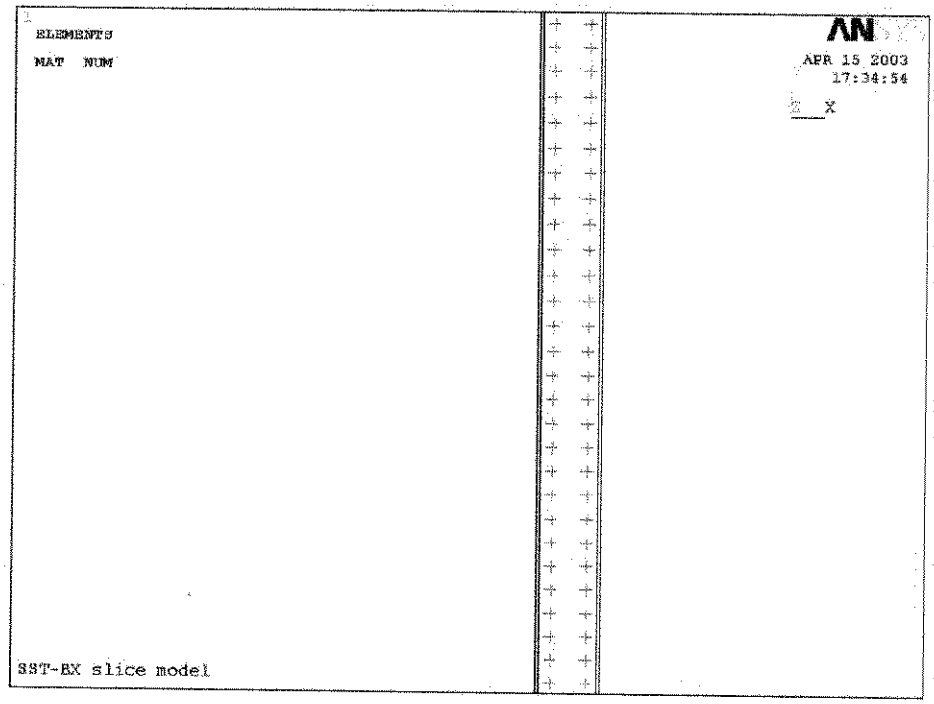

Figure 12. Rebar orientation at tank wall

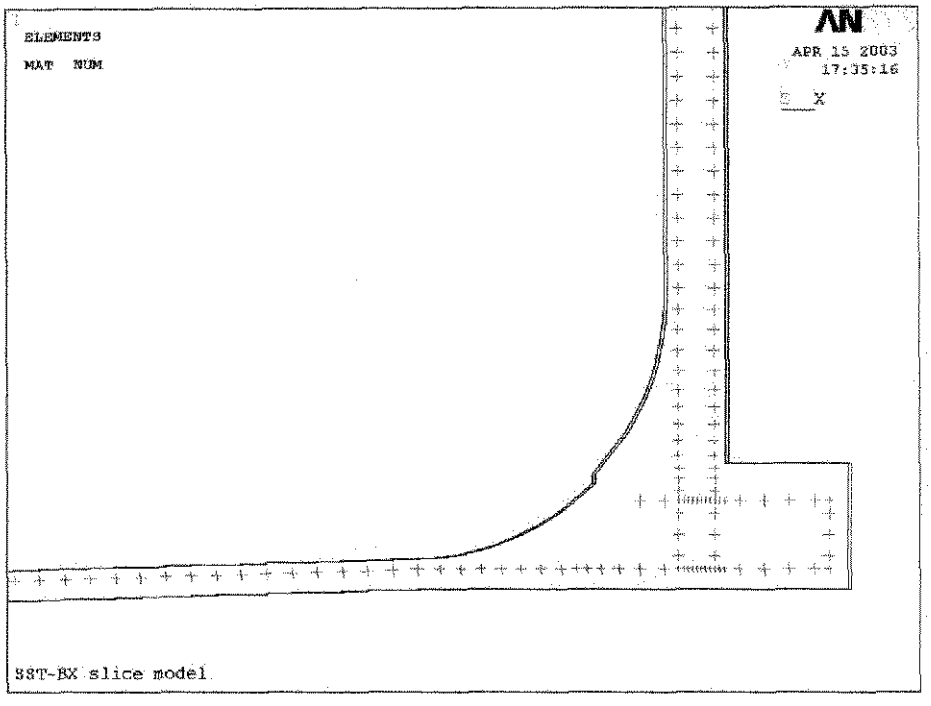

Figure 13. Rebar orientation at wall/slab joint

4.0 RESULTS

The solution can be obtained by running the master input macro **sst_bx_slice.mac** (see attachment), which loads the macro defining the parameters, creates the tank/soil geometry and finite element mesh, applies loads, and defines the material properties and real constants.

Figures 14 and 15 summarize the displacement response due to AOR loads identified in Section 3. The peak displacement of the soil mass is 1.67 inches, and this occurs at grade far away from the tank. The peak tank displacement is 1.37 inches, at the dome apex. Figures 16 and 17 show exaggerated views of the tank/soil displacement.

The von Mises equivalent stress contours are presented in Figures 18 and 19. The peak equivalent stress in the tank is approximately 2.0 ksi, and this occurs at the joint of the tank wall and slab. The hoop stress of the tank is shown in Figure 20. The maximum hoop stress is about 532 psi at the haunch region, and the minimum hoop stress is -523 psi at the dome center. The rebar stresses in the first, second, and third rebar directions are plotted in Figures 21 to 26.

Force and moment resultants are calculated in **pst_bx_slice.mac**. In order for **pst_bx_slice.mac** to generate correct results, the tank has to be map meshed. The mapped mesh results in a set of nodes aligned in a straight line, creating a cross section for section force and moment evaluation. Once the cross section nodes and elements attached to one side of the nodes are selected, the macro **get_res_slice.mac** then calculates the nodal forces, determines the location of the neutral axis, and evaluates the moment about the neutral axis. The force and moment per unit length are calculated according to the radius of the neutral axis. The section hoop force is calculated in macro **get_hpfrc.mac**. The nodal hoop stresses are retrieved and averaged over the thickness. The hoop force over the meridional length is then obtained from the averaged nodal hoop stress and wall thickness. Figures 27 to 30 show the axial force, shear force, hoop force, and moment, respectively. The maximum axial force of about 77 kip/ft occurs at dome center. The maximum shear force of 31 kip/ft is located at the wall/slab joint. The maximum moment of 712 kip-in/ft and maximum hoop force of 117 kip/ft are observed at the haunch region.

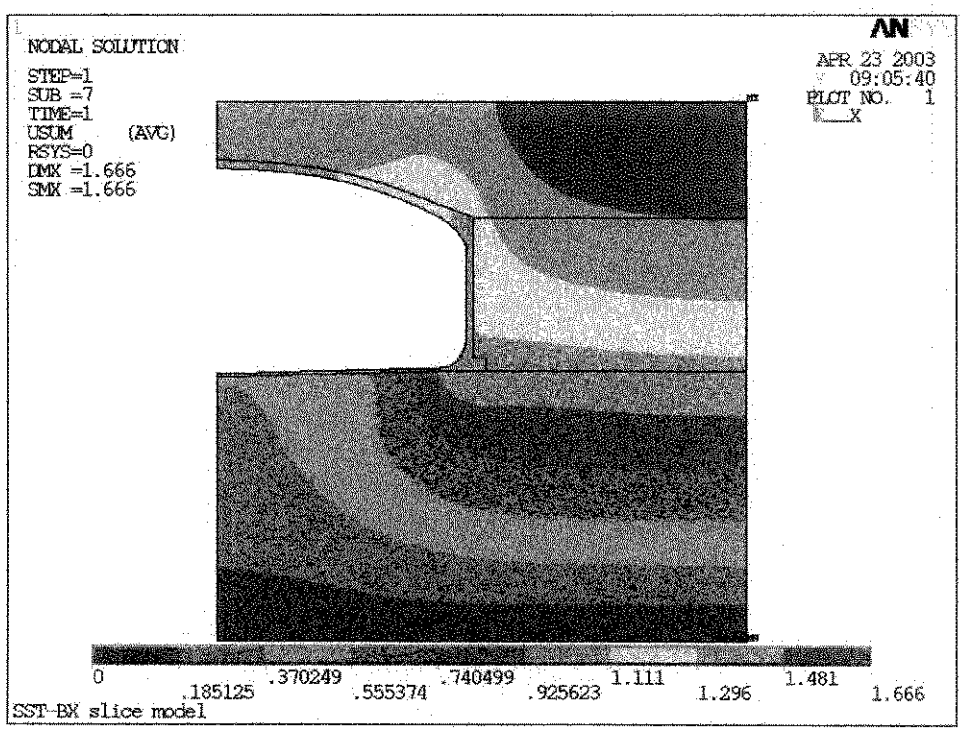

Figure 14. Total displacement contour of soil and tank

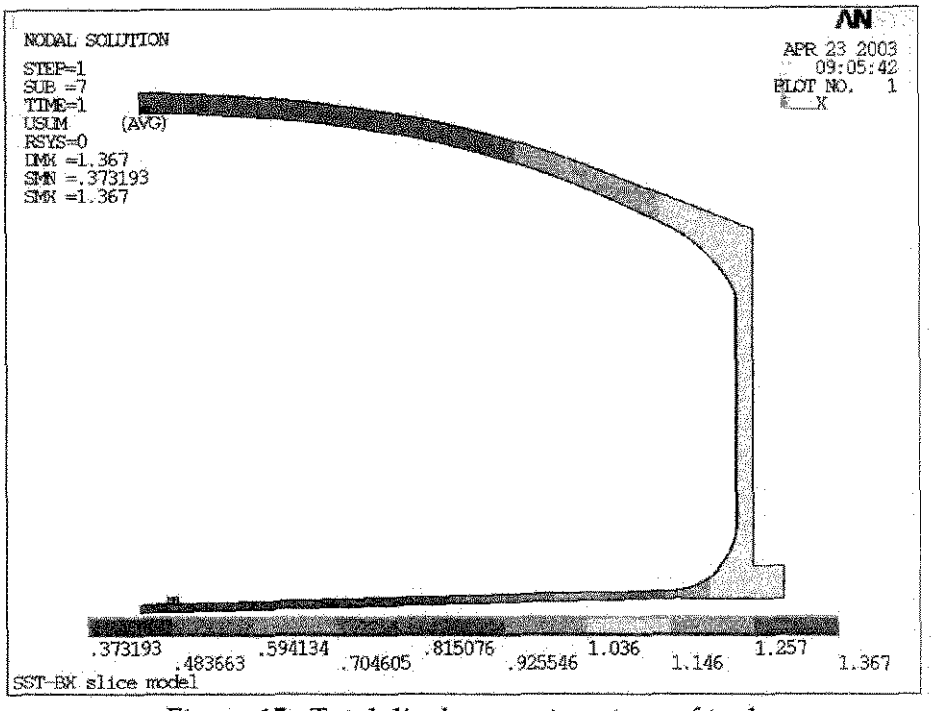

Figure 15. Total displacement contour of tank

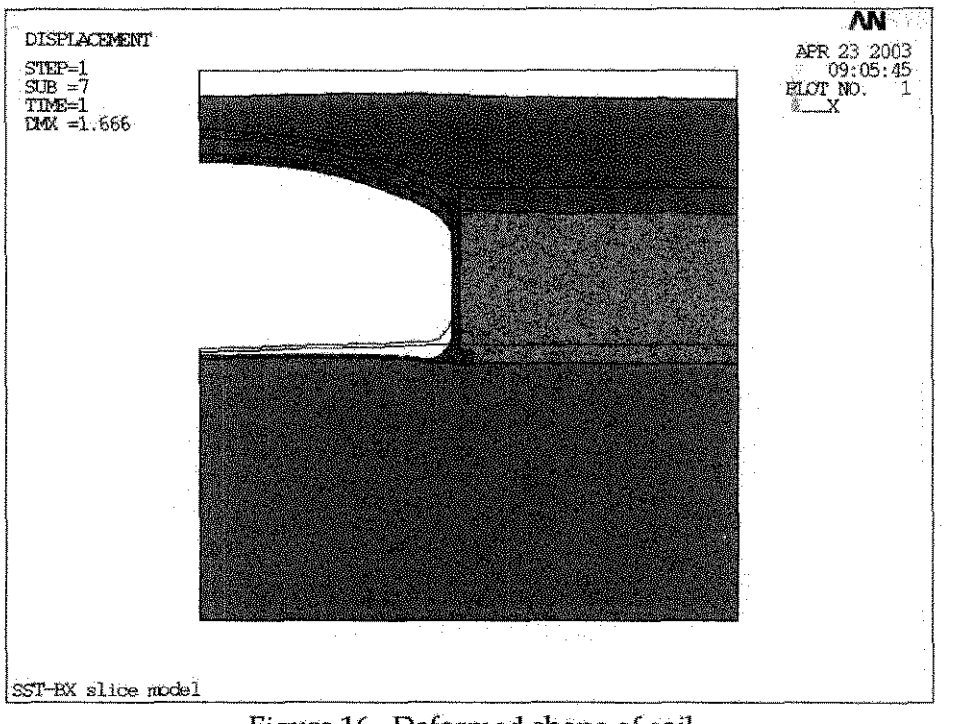

Figure 16. Deformed shape of soil

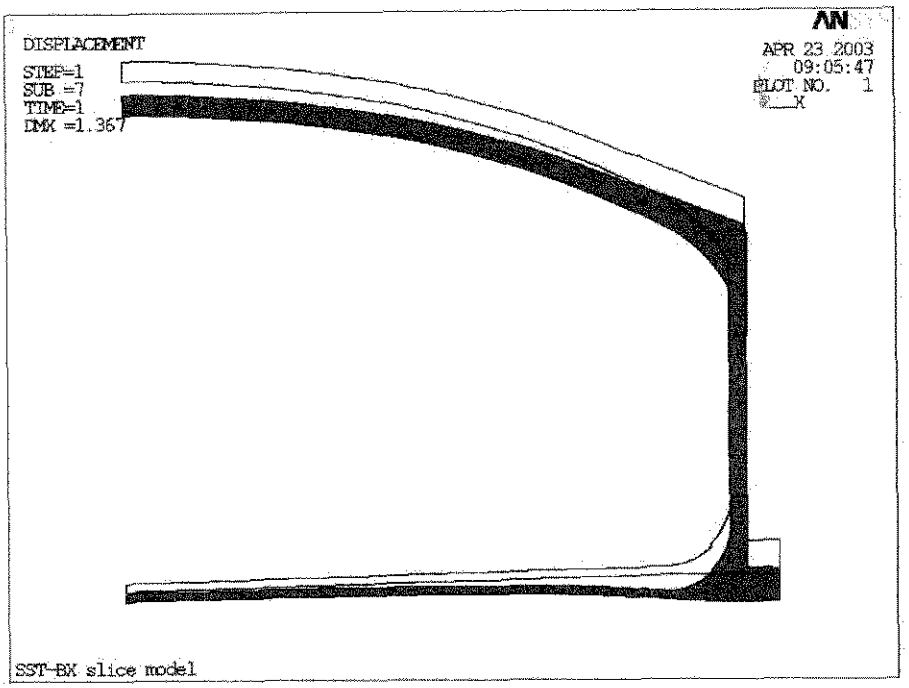

Figure 17. Deformed shape of tank

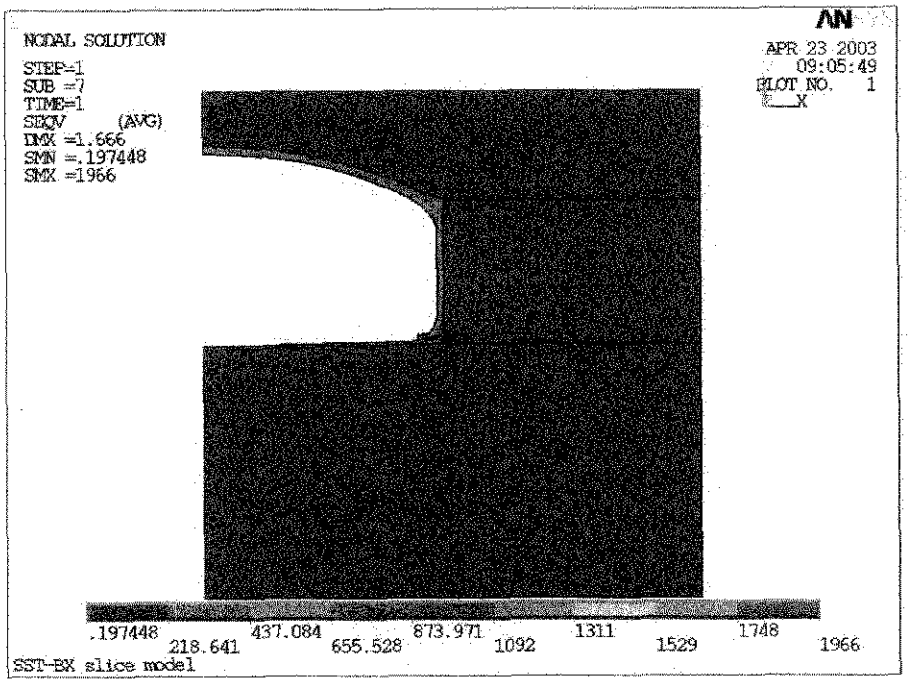

Figure 18. Equivalent stress contours of tank and soil (psi).

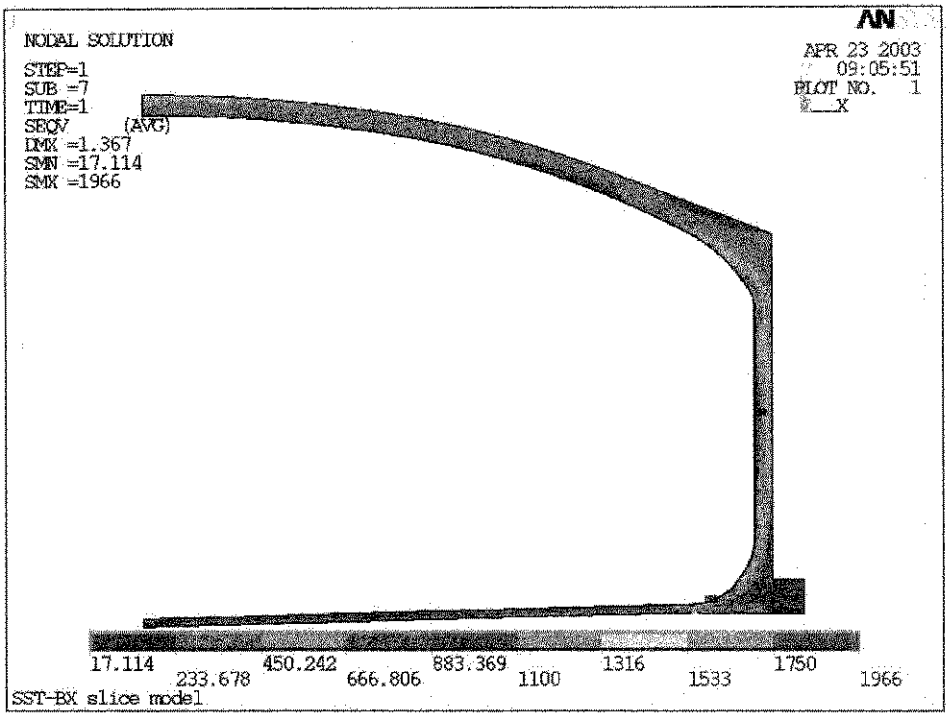

Figure 19. Equivalent stress contours of tank (psi).

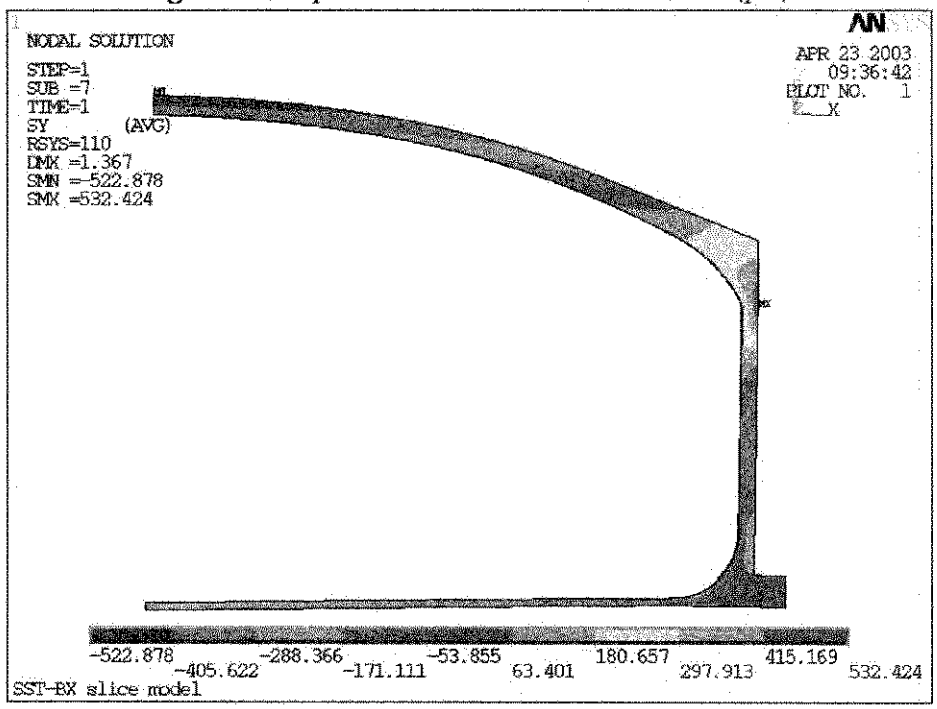

Figure 20. Hoop stress of tank (psi)

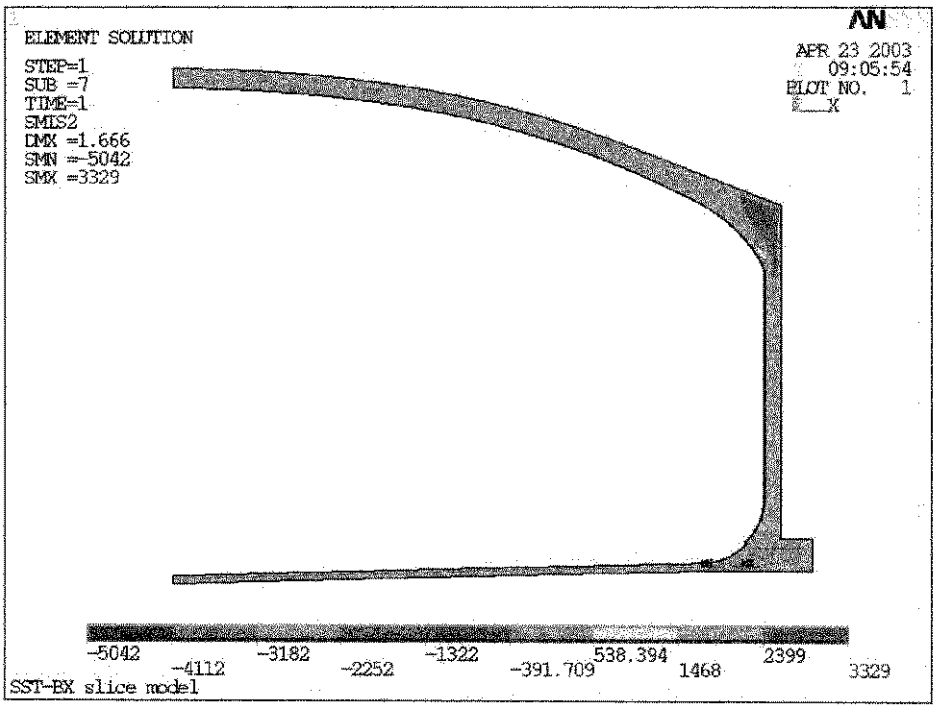

Figure 21. Rebar stresses in first rebar direction

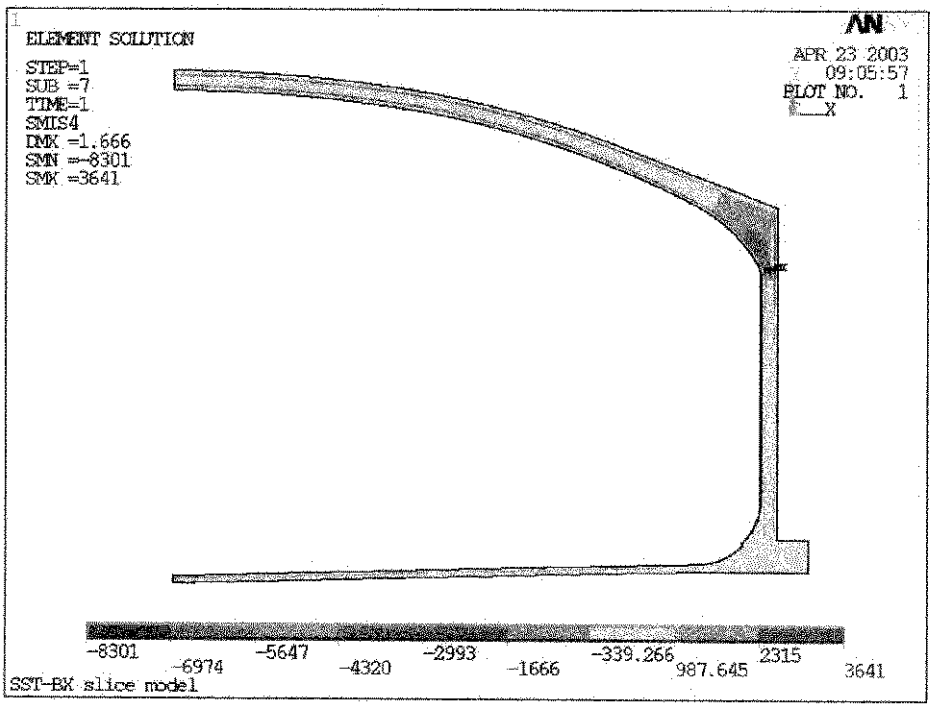

Figure 22. Rebar stresses in second rebar direction

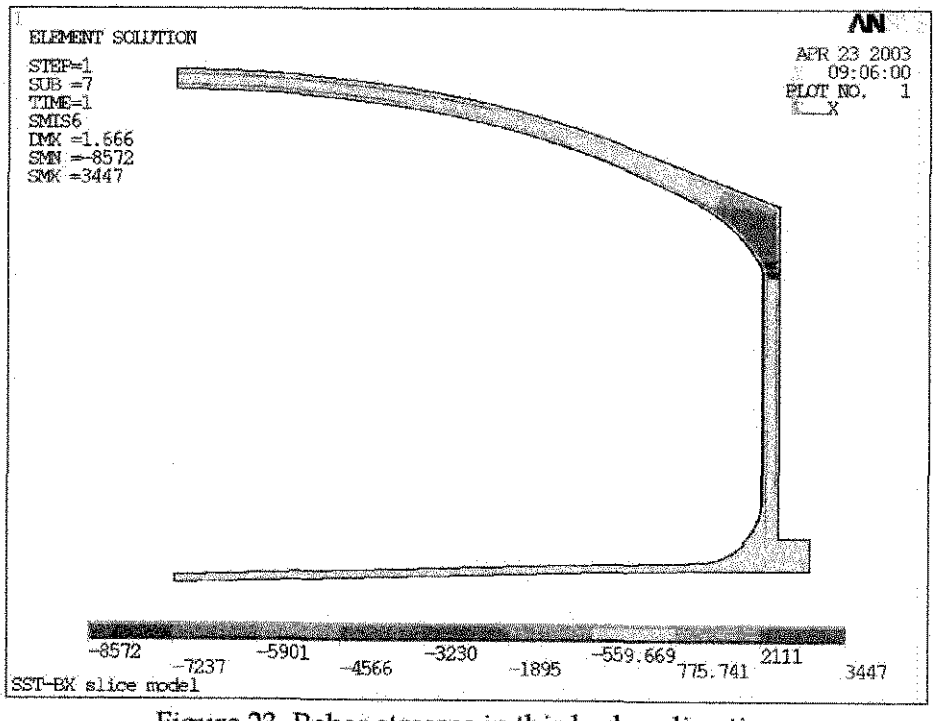

Figure 23. Rebar stresses in third rebar direction

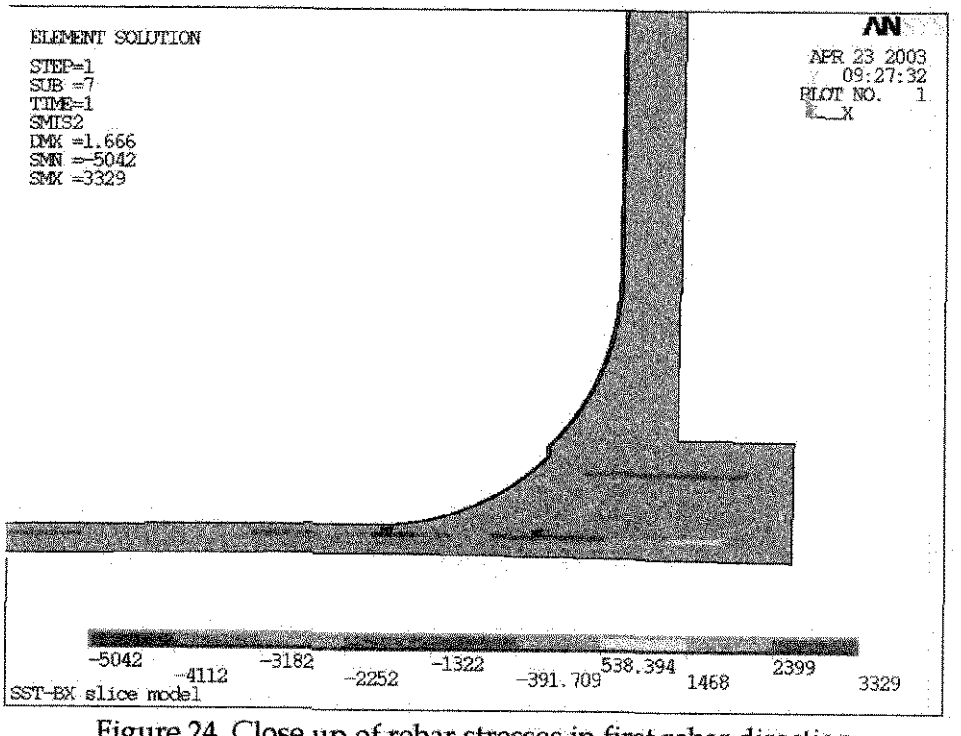

Figure 24. Close up of rebar stresses in first rebar direction

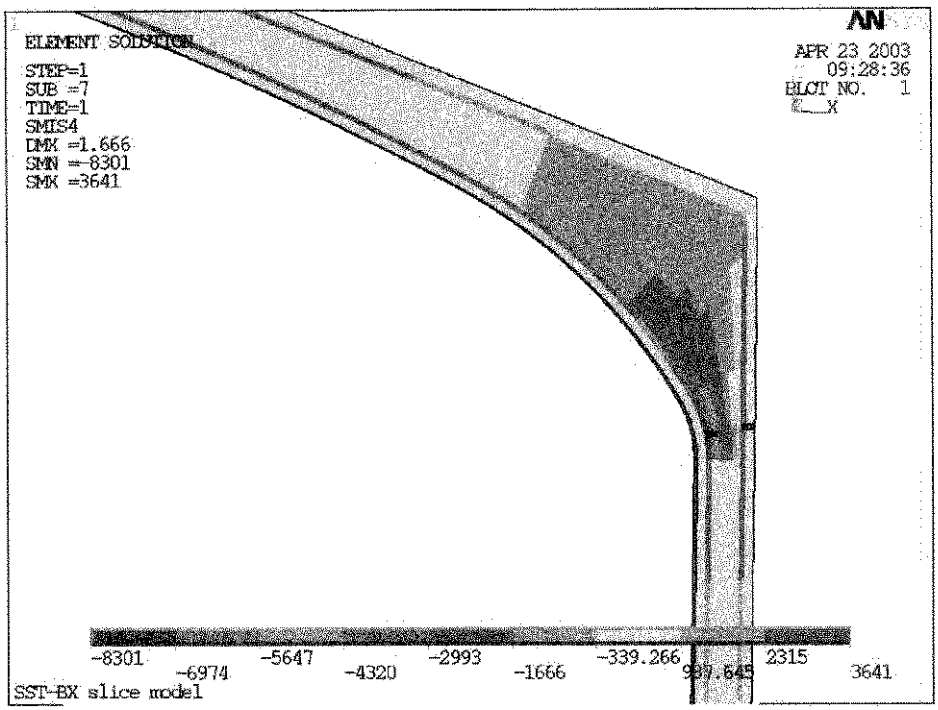

Figure 25. Close up of rebar stresses second rebar direction

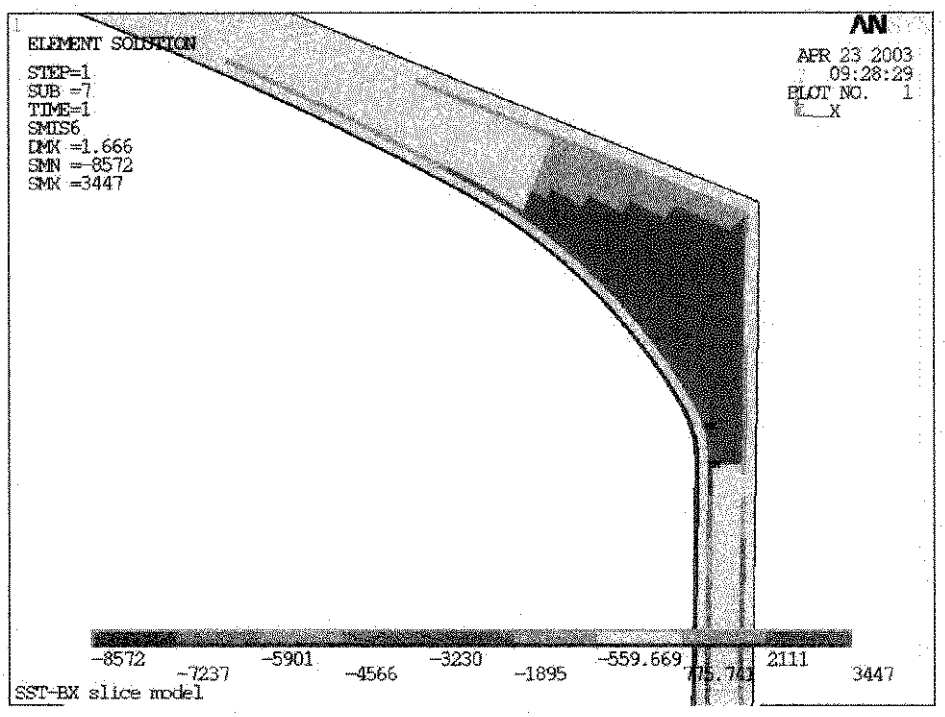

Figure 26. Close up of rebar stress in third rebar direction

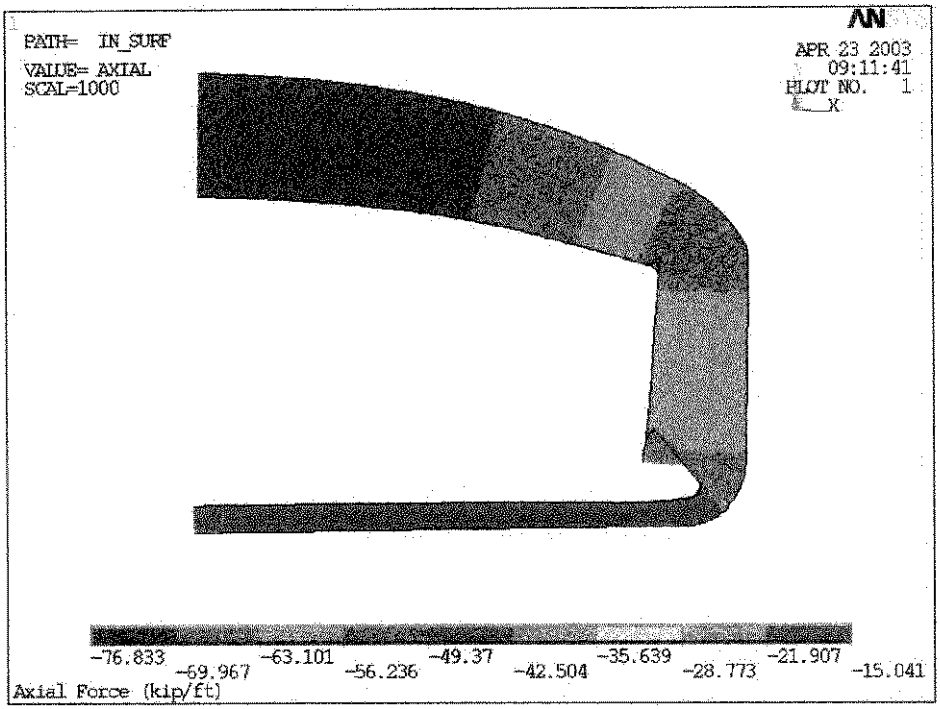

Figure 27. Unit section axial force (kip/ft)

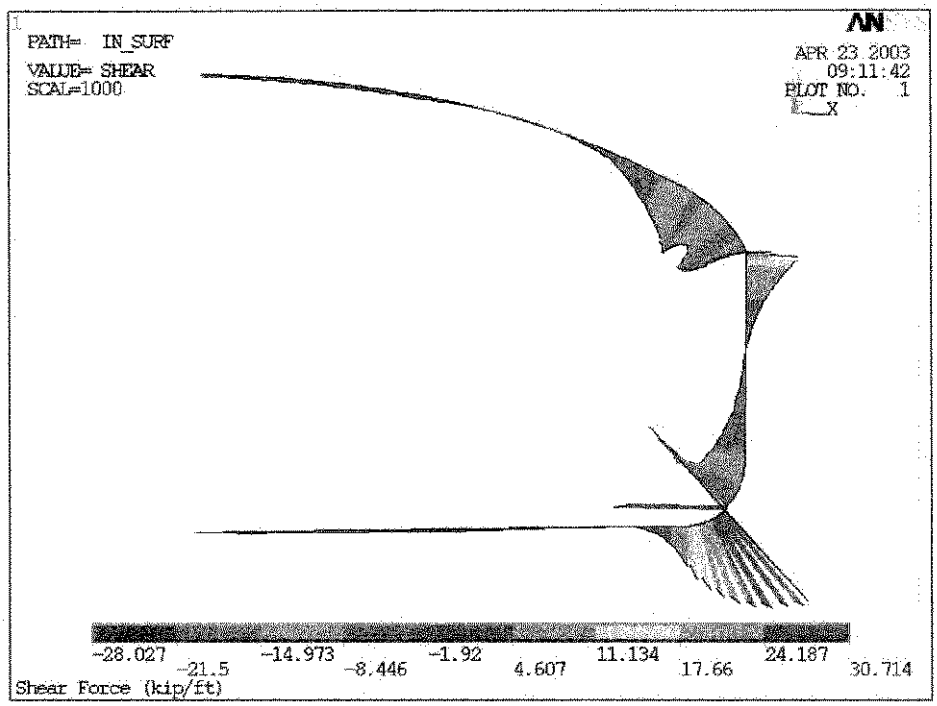

Figure 28. Unit section shear force (kip/ft)

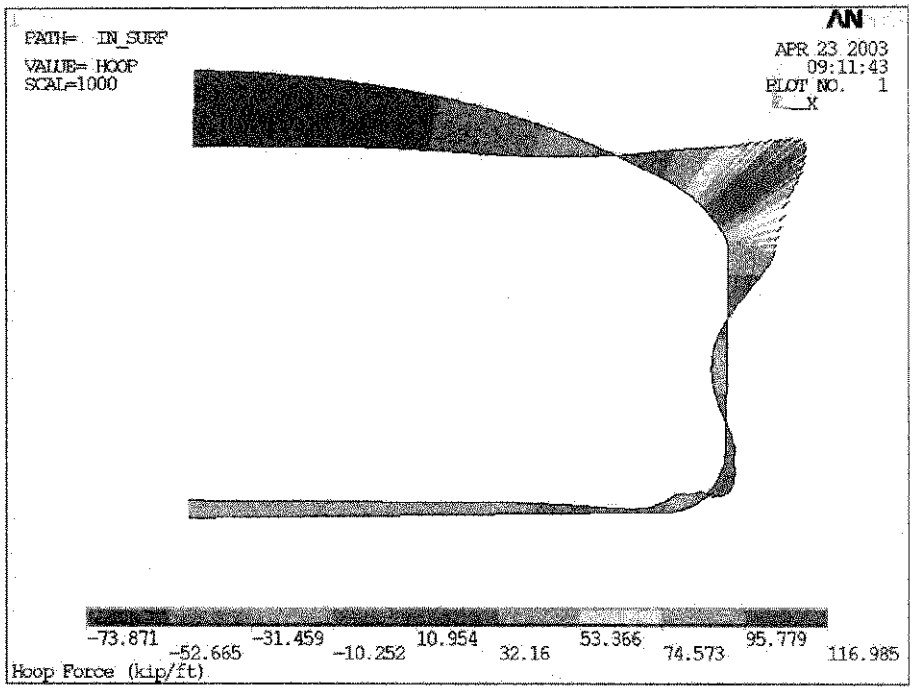

Figure 29. Unit section hoop force (kip/ft)

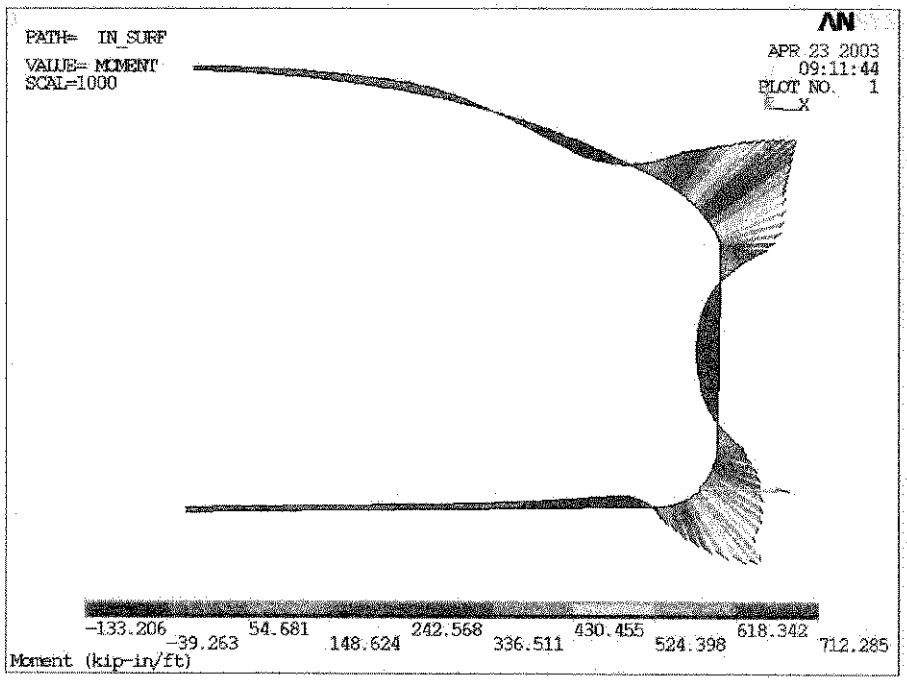

Figure 30. Unit section moment (kip-in/ft)

5.0 CONCLUSIONS

The 3D parametric slice model is capable of giving a more accurate estimation, compared with the 2D linear model, of tank behavior under AOR loads because of the inclusion of contact and soil plasticity. A sample calculation demonstrates the use of the parametric model for tank SST-BX, and provides examples of the types of inputs that can be defined and the types of outputs that can be obtained. The parametric model can be used effectively to evaluate the tank response to a broad range of loading conditions and material properties.

6.0 REFERENCES

[Ref_1] ANSYS 7.0 General-Purpose Finite Element Analysis Program, ANSYS Inc.

[Ref_2] M&D Professional Services, "Dome Load Evaluation for Hanford 241-C Farm 100-Series Tanks", Document Number RPP-14249, January 14, 2003.

[Ref_3] Statement of Work, Requisition #92879, "Development of ANSYS Finite Element Models for SST and DST Tanks," Revision 1, February 24, 2003.

[Ref_4] Drawing H-2-602, April 1, 1947

7.0 ATTACHMENTS AND APPENDICES

sst_bx_slice.mac

```
!--Create cross section of SST BX tank
finish
/clear
/prep7

SHPP,MODIF,1,100000,

/INPUT,'parm_bx','mac'

!--Create dome
/TRIAD,RTOP
wpcsys,-1,0
csys,4
k,1,r1,-h1
k,2,r2,-h2
k,3,r3,-h3
k,4,r4,-h4
k,5,r5,-h5
k,6,r6,-h6
k,7,r7,-h7
k,8,r8,-h8
k,9,r9,-h9
k,10,r10,-h10
k,11,r11,-h11
k,12,r12,-h12
k,13,r13,-h13
k,14,r14,-h14
k,15,r15,-h15
k,16,r16,-h16
k,17,r17,-h17
k,18,r18,-h18
k,19,r19,-h19

larc,1,2,10,dm_r1
larc,2,3,10,dm_r3
lstr,3,4
lstr,4,5
lstr,5,6
lstr,6,7
lstr,7,8
lstr,8,9
lstr,9,10
lstr,10,11
larc,11,12,1,bot_r2
lstr,12,13
larc,13,14,1,bot_r1
```

```
lstr,14,15
larc,15,16,10,hnch_r2
larc,16,17,10,hnch_r1
larc,17,18,10,dm_r4
larc,18,19,10,dm_r2
lstr,1,19
al,all

!--Cut Tank
lstr,2,18
asbl,1,20

lwpla,-1,2,1
lsbw,17
lstr,3,20
asbl,3,17

wpcsys,-1,0
kwpave,4
wprot,,,90
wpoff,,,-42   !to cut the haunch core region
lsbw,3

lwpla,-1,14,1
asbw,all

lwpla,-1,23
kwpave,17
asbw,3
lwpla,-1,24,1
asbw,6

lwpla,-1,5
asbw,5
lwpla,-1,32
asbw,8


larc,12,14,1,bot_r2
asbl,9,33

lwpla,-1,14
asbw,10

cm,a_tank,area

!---Create Soil Mass
wpcsys,-1,0
kwpave,1
csys,4
wpoff,,depth
```

```
rectng,0,soil_r,0,-(h9+depth+soil_h)
aovlp,all

adele,12,,,1
cmsel,u,a_tank
cm,a_soil,area

!--cut soil for different soil properties
kwpave,4
wprot,,90
asbw,all
kwpave,7
asbw,all
cm,a_soil,area

wpcsys,-1,0
wprot,,,90
kwpave,1
wpoff,,,cload_l
lsbw,38

allsel
aplot

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Cut tank for rebar regions at different depths
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
cmsel,s,a_tank
asel,u,,,8
cm,a_tank,area

rbar_t=1.
rbar_dep1=3 !bar clearance for rebar @ dome
rbar_dep2=2 !bar clearance for rebar @ wall
rbar_dep3=1.5     !bar clearance for rebar @ slab
rbar_dep4=3.5     !bar clearance for slab end
rbar_dep5=6.75  !bar clearance for top rebar at slab end
rbar_dep6=3.5     !bar clearance for bottom rebars @ slab end
rbar_dep7=1.5     !bar clearance for rebars @slab bottom
rbar_dep8=2 !bar clearance for rebars @haunch

rbar_r1=6.25*12   !radial bar lengths in dome
rbar_r2=10*12
rbar_r3=20*12
rbar_r4=30*12
rbar_r5=32*12
rbar_r6=32*12+32

slb_rbar_r1=40
```

```
rbar_wll_dh1=+6          !vertical rebar to wall step distance
rbar_wll_dh2=rbar_wll_dh1+10
rbar_wll_dh3=rbar_wll_dh2+4*12
rbar_wll_dh4=rbar_wll_dh3+56
rbar_wll_dh5=rbar_wll_dh4+60
rbar_wll_dh6=rbar_wll_dh5+18

rbar_wll_dh7=25*12-2*12
rbar_wll_dh8=25*12-1*12
rbar_wll_dh9=11*12
rbar_wll_dh10=rbar_wll_dh4+5

wpcsys,-1,0
kwpave,1
wpoff,,-rbar_dep1
csys,4
k
wpoff,,-rbar_t
k

kwpave,19
wpoff,,rbar_dep1
k
wpoff,,rbar_t
k

lwpla,-1,20
wpoff,,,rbar_dep1
k
wpoff,,,rbar_t
k

lwpla,-1,20,1
wpoff,,,-rbar_dep1
k
wpoff,,,-rbar_t
k

lwpla,-1,17
wpoff,,,rbar_dep1
k
wpoff,,,rbar_t
k

lwpla,-1,27
wpoff,,,rbar_dep8
k
wpoff,,,rbar_t
k
```

```
lwpla,-1,29
wpoff,,,rbar_dep1
k
wpoff,,,rbar_t
k

lwpla,-1,30
wpoff,-rbar_dep8
k
wpoff,-rbar_t
k

lwpla,-1,25
wpoff,,,rbar_dep2
k
wpoff,,,rbar_t
k

lwpla,-1,25,1
wpoff,,,-rbar_dep2
k
wpoff,,,-rbar_t
k

larc,34,38,10,dm_r1-rbar_dep1
larc,35,39,10,dm_r1-rbar_dep1-rbar_t
larc,37,41,10,dm_r2+rbar_dep1+rbar_t
larc,36,40,10,dm_r2+rbar_dep1
larc,38,42,10,dm_r3-rbar_dep1
larc,43,39,10,dm_r3-rbar_dep1-rbar_t
larc,45,41,10,dm_r4+rbar_dep1+rbar_t
larc,44,40,10,dm_r4+rbar_dep1
larc,45,49,10,hnch_r1+rbar_dep8+rbar_t
larc,44,48,10,hnch_r1+rbar_dep8
larc,51,49,10,hnch_r2+rbar_dep8+rbar_t
larc,50,48,10,hnch_r2+rbar_dep8

lsbl,52,17
lsbl,53,17

asel,s,,,2
lsel,s,,,38
lsel,a,,,47,49
asbl,all,all

asel,s,,,1
lsel,s,,,50,52
lsel,a,,,58
asbl,all,all

asel,s,,,4
```

```
lsel,s,,,59,60
asbl,all,all

allsel
lsbl,54,29
lsbl,55,29
asel,s,,,3
lsel,s,,,27
lsel,a,,,54
asbl,all,all

asel,s,,,7
lsel,s,,,56,57
lsel,a,,,75,76
asbl,all,all
allsel

lwpla,-1,30
asbw,3
asbw,27
asbw,28

lwpla,-1,71
asbw,24
asbw,25
asbw,29
kwpave,42
asbw,25
asbw,32
asbw,33

lwpla,-1,29
kwpave,52
asbw,7
asbw,9
asbw,29
asbw,34
asbw,35
kwpave,53
asbw,38
asbw,39
asbw,40
asbw,41
asbw,42

kwpave,51
asbw,44
kwpave,50
asbw,48

kwpave,67
```

```
asbw,11
kwpave,73
asbw,50
kwpave,77
asbw,51
kwpave,78
asbw,52

lwpla,-1,6
asbw,8
asbw,11
asbw,48
asbw,50
asbw,51
asbw,53

!--cut slab end for rebar regions
wpoff,,,rbar_dep5
asbw,6
asbw,55
asbw,56
asbw,57
asbw,58
asbw,59
wpoff,,,rbar_t
asbw,6
asbw,55
asbw,56
asbw,57
asbw,58
asbw,60

kwpave,12
asbw,53
asbw,61
asbw,62
asbw,63
asbw,64
asbw,65

kwpave,7
wpoff,,,-rbar_dep6
asbw,6
asbw,55
asbw,56
asbw,58
asbw,59
asbw,70
wpoff,,,-rbar_t
asbw,65
asbw,79
```

```
asbw,80
asbw,81
asbw,82
asbw,83

lwpla,-1,5,1
wpoff,,,-rbar_dep4
asbw,56
asbw,60
asbw,71
asbw,72
asbw,80
asbw,87
wpoff,,,-rbar_t
asbw,56
asbw,60
asbw,71
asbw,72
asbw,80
asbw,90

!--Cut slab bottom for rebar regions
lwpla,-1,9,1
wpoff,,,-rbar_dep7
lsbw,9
wpoff,,,-rbar_t
lsbw,209
lstr,122,137
lstr,115,138

lsel,s,,,209
lsel,a,,,235
asel,s,,,5
asbl,all,all
allsel

!--cut wall bottom
lwpla,-1,218,1
wpoff,,,slb_rbar_r1
asbw,57
asbw,59
asbw,77
asbw,82
asbw,89

kwpave,101
asbw,105
asbw,107
asbw,108

!--Cut wall for vertical divisions
```

```
allsel
cmsel,u,a_soil
lwpla,-1,36
kwpave,5
wpoff,,,rbar_wll_dh1
asbw,all

kwpave,5
wpoff,,,rbar_wll_dh2
asbw,all

kwpave,5
wpoff,,,rbar_wll_dh3
asbw,all

kwpave,5
wpoff,,,rbar_wll_dh4
asbw,all

kwpave,5
wpoff,,,rbar_wll_dh5
asbw,all

kwpave,5
wpoff,,,rbar_wll_dh6
asbw,all

cm,a_tank,area

!--Cut dome
wpcsys,-1,0
kwpave,1
wprot,,,90
wpoff,,,rbar_r1
lsbw,1

kwpave,1
wpoff,,,rbar_r2
lsbw,261

kwpave,1
wpoff,,,rbar_r3
lsbw,2

kwpave,1
wpoff,,,rbar_r4
lsbw,4

kwpave,1
wpoff,,,rbar_r5
lsbw,309
```

```
lwpla,-1,311,1
asbw,1
asbw,23
asbw,25
asbw,28

asbw,36

lwpla,-1,311
asbw,1
asbw,25
asbw,114
asbw,129
asbw,148

lwpla,-1,308,1
asbw,2
asbw,19
asbw,20
asbw,21
asbw,22

lwpla,-1,287,1
asbw,12
asbw,15
asbw,16
asbw,17
asbw,18

lwpla,-1,287
asbw,15
asbw,16
asbw,17
asbw,159
asbw,160
cm,a_tank,area

wpcsys,-1,0
wprot,,,90
kwpave,1
wpoff,,,rbar_r6
lsbw,28
lwpla,-1,379,1
asbw,4
asbw,24
asbw,26
asbw,32
asbw,37

lwpla,-1,130
```

```
asbw,5
asbw,59
asbw,109
asbw,110
asbw,111

lwpla,-1,12,1
asbw,53
asbw,54
asbw,61
asbw,62
asbw,63
asbw,64
asbw,87
asbw,91
asbw,96
cm,a_tank,area

asel,s,,,5
asel,a,,,37
asel,a,,,178
aadd,all
cmsel,a,a_tank
aadd,53,184
cm,a_tank,area
lcomb,139,155

asel,s,,,9
asel,a,,,34
asel,a,,,41
asel,a,,,45
aadd,all
cmsel,a,a_tank
cm,a_tank,area

kwpla,-1,76,4
wprot,,90
asbw,30
asbw,31
asbw,37
asbw,46

lwpla,-1,113,1
wprot,,,90
asbw,45

lstr,237,70
asbl,31,75

aadd,39,178
aadd,46,47
```

```
aadd,29,184
aadd,40,45

lsel,s,,,34
lsel,a,,,101
lsel,a,,,115
lcomb,all
lsla


lsel,s,,,82
lsel,a,,,90
lsel,a,,,94
lcomb,all
lsla

lcomb,113,389
lcomb,75,92
cm,a_tank,area

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!--Set Elelment types
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
r_liner=1
r,1,liner_t

!mat_liner=1
mat_conc=2  !structural concrete in tank
mat_tsoil=3 !for top soil
mat_msoil=4     !for mid soil
mat_bsoil=5 !for bottom soil
mat_rebar=6
mat_srebar=7

type_2d_liner=1
type_2d_conc=2
type_2d_soil=3
type_2d_rebar=4

type_3d_conc=type_2d_conc+10
type_3d_soil=type_2d_soil+10
type_3d_rebar=type_2d_rebar+10

!et,type_liner,shell61
et,type_2d_conc,plane42
et,type_2d_soil,plane42
et,type_2d_rebar,plane42

et,type_3d_conc,solid65
```

```
et,type_3d_soil,solid45
et,type_3d_rebar,solid65

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!-----set material properties
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]

![1]                 steel (for liner)
mp,ex,mat_liner,steel_ex
mp,dens,mat_liner,steel_dens
mp,prxy,mat_liner,steel_prxy
mp,alpx,mat_liner,steel_alpx
mp,kxx,mat_liner,steel_kx
mp,c,mat_liner,steel_c

![2]                 structural concrete
mp,ex,mat_conc,conc_ex
mp,dens,mat_conc,conc_dens
mp,prxy,mat_conc,conc_prxy
mp,alpx,mat_conc,conc_alpx
mp,kxx,mat_conc,conc_kx
mp,c,mat_conc,conc_c

*if,crush_id,eq,1,then
   tb,concr,mat_conc
   tbdata,1,conc_open,conc_closed,conc_crack,conc_crush
*endif

*if,usr_crp_id,eq,1,then
   tb,creep,mat_conc,,,100
   tbdata,1,c1,c2,c3,c4,c5
   tbdata,6,c6,c7,c8,c9,c10,c11
*endif

![3]                 top soil
mp,ex,mat_tsoil,tsoil_ex
mp,dens,mat_tsoil,tsoil_dens
mp,prxy,mat_tsoil,tsoil_prxy
tb,dp,mat_tsoil,,,0
tbdata,1,tsoil_cohesion,tsoil_friction,tsoil_dilat

![4]                 mid soil
mp,ex,mat_msoil,msoil_ex
mp,dens,mat_msoil,msoil_dens
mp,prxy,mat_msoil,msoil_prxy
tb,dp,mat_msoil,,,0
tbdata,1,msoil_cohesion,msoil_friction,msoil_dilat

![5]                 bottom soil
```

```
mp,ex,mat_bsoil,bsoil_ex
mp,dens,mat_bsoil,bsoil_dens
mp,prxy,mat_bsoil,bsoil_prxy
tb,dp,mat_bsoil,,,0
tbdata,1,bsoil_cohesion,bsoil_friction,bsoil_dilat

![6]              rebar
mp,ex,mat_rebar,rebar_ex
mp,dens,mat_rebar,rebar_dens
mp,prxy,mat_rebar,rebar_prxy

![7]              slab rebar
mp,ex,mat_srebar,srebar_ex
mp,dens,mat_srebar,srebar_dens
mp,prxy,mat_srebar,srebar_prxy

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!---Assign attribute to areas, real constants will be defined later
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
cmsel,s,a_tank
aatt,2,700,type_2d_conc

!-- slab rebar
asel,s,,,103
aatt,mat_conc,100,type_2d_rebar

asel,s,,,105,109,4
asel,a,,,177
aatt,mat_conc,101,type_2d_rebar

asel,s,,,72
asel,a,,,77,79,2
asel,a,,,84,85
asel,a,,,88
asel,a,,,100

aatt,mat_conc,102,type_2d_rebar

asel,s,,,56
asel,a,,,66,69
asel,a,,,104
aatt,mat_conc,103,type_2d_rebar

asel,s,,,97
asel,a,,,99,100
aatt,mat_conc,104,type_2d_rebar

asel,s,,,62
asel,a,,,73
```

```
asel,a,,,76
asel,a,,,111
asel,a,,,179
asel,a,,,183
aatt,mat_conc,105,type_2d_rebar

asel,s,,,81,86,5
aatt,mat_conc,106,type_2d_rebar

!--- Wall rebar
asel,s,,,38
asel,a,,,49
asel,a,,,144,147,3
aatt,mat_conc,201,type_2d_rebar

asel,s,,,139
asel,a,,,142
aatt,mat_conc,202,type_2d_rebar

asel,s,,,135,136
aatt,mat_conc,203,type_2d_rebar

asel,s,,,48
asel,a,,,52
asel,a,,,116
asel,a,,,132
aatt,mat_conc,204,type_2d_rebar

asel,s,,,125,128,3
aatt,mat_conc,205,type_2d_rebar

asel,s,,,120,122,2
aatt,mat_conc,206,type_2d_rebar

!---Dome rebar
asel,s,,,16
asel,a,,,164
aatt,mat_conc,300,type_2d_rebar

asel,s,,,18
asel,a,,,166
aatt,mat_conc,301,type_2d_rebar

asel,s,,,19
asel,a,,,21
asel,a,,,161
asel,a,,,163
aatt,mat_conc,302,type_2d_rebar

asel,s,,,129
asel,a,,,149
```

```
asel,a,,,156,158,2
aatt,mat_conc,303,type_2d_rebar

asel,s,,,36
asel,a,,,153
aatt,mat_conc,304,type_2d_rebar

asel,s,,,24,32,4
asel,a,,,117
asel,a,,,171,173,2
aatt,mat_conc,305,type_2d_rebar

asel,s,,,39
aatt,mat_conc,306,type_2d_rebar

asel,s,,,43
asel,a,,,29
aatt,mat_conc,307,type_2d_rebar

asel,s,,,27
asel,a,,,30
asel,a,,,41
aatt,mat_conc,308,type_2d_rebar

!----Haunch core
asel,s,,,37
asel,a,,,53
aatt,mat_conc,500,type_2d_rebar

asel,s,,,35
aatt,mat_conc,501,type_2d_rebar

allsel

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     2D Meshing
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]

!-- tank mesh
cmsel,s,a_tank
asel,u,,,8
allsel,below,area

esize,tank_size
type,type_2d_conc
mat,mat_tank

lsel,s,,,130
lsel,a,,,244
```

```
lccat,all
lsla

lsel,s,,,105
lsel,a,,,117
lccat,all
lsla

lsel,s,,,236
lsel,a,,,252
lsel,a,,,391
lccat,all
lsla

lsel,s,,,143
lsel,a,,,151
lccat,all
lsla

lesize,9,,,2
lesize,32,,,2
mshkey,1
amesh,all

asel,a,,,8
mshkey,0
amesh,8

!-- soil mesh
cmsel,s,a_soil
allsel,below,area

esize,soil_esize
type,type_2d_soil

mopt,trans,1.25
mopt,expnd,1.25

lesize,41,,,10,4
lesize,42,,,35,4
lesize,39,,,30,6
lesize,37,,,30,5
lesize,46,,,cload_div,4
lesize,43,,,40,.25
lesize,40,,,10

mshkey,0
amesh,all

wpcsys,-1,0
kwpave,1
```

```
csys,4
cmsel,s,a_soil
asel,r,loc,y,-h4,999999
cm,t_soil,area
esla
emodif,all,mat,mat_tsoil

cmsel,s,a_soil
asel,r,loc,y,-h7,-h3
cm,m_soil,area
esla
emodif,all,mat,mat_msoil

cmsel,s,a_soil
asel,r,loc,y,-h7,-99999
cm,b_soil,area
esla
emodif,all,mat,mat_bsoil

allsel
!dele concatenated lines
CM,_Y,LINE
*SET,_Z1,LSINQR(0,13)
*IF,_z1,ne,0,then
LSEL,R,LCCA
*SET,_Z2,LSINQR(0,13)
LDELE,ALL
*SET,_Z3,_Z1-_Z2
*IF,_Z3,NE,0,THEN
CMSEL,S,_Y
CMDELE,_Y
*ENDIF
*ELSE
CMSEL,S,_Y
CMDELE,_Y
*ENDIF

![[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[
!
!     3D mesh by rotation, reassign general elem. attr.
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
allsel
type,type_3d_soil
extopt,attr,1,1,1
extopt,esize,1
vrotat,all,,,,,,10,19,slice_ang

cmsel,s,a_tank
vsla
eslv
```

```
emodif,all,type,type_3d_conc

cmsel,s,t_soil
vsla
eslv
emodif,all,mat,mat_tsoil

cmsel,s,m_soil
vsla
eslv
emodif,all,mat,mat_msoil

cmsel,s,b_soil
vsla
eslv
emodif,all,mat,mat_bsoil

asel,s,type,,type_2d_rebar
vsla
eslv
emodif,all,type,type_3d_rebar

cmsel,s,a_soil
vsla
allsel,below,volu
cm,junk,volu
vgen,2,all
cm,v_soil,volu
cmsel,s,junk
allsel,below,volu
aclear,all
vclear,all
vdele,all,,,1
allsel


!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!    Create local coordinate systems
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!--- csys 100 spheroid: for internal dome/haunch rebar/interior haunch
!    the x and y radius ratio are from error-and-try process
!
a=450
b=145.75
wpcsys,-1,0
kwpave,36
wpoff,,-b
cswpla,100,2,b/a,b/a
```

```
!--- csys 101 sperical: external dome/haunch
a=600
b=300

wpcsys,-1,0
kwpave,35
wpoff,,-b
cswpla,101,2,b/a,b/a

!--- csys 110 cylindrical: wall and slab rebars
wpcsys,-1,0
wprot,,-90
cswpla,110,1


!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Assign esys to rebar elem.
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]

!--- dome rebar
asel,s,,,16
asel,a,,,21,30,3
asel,a,,,35,37
asel,a,,,41
asel,a,,,53
asel,a,,,117
asel,a,,,149
asel,a,,,158
asel,a,,,163
asel,a,,,166
asel,a,,,171
vsla
eslv
emodif,all,esys,100

asel,s,,,18,19
asel,a,,,28
asel,a,,,32
asel,a,,,39
asel,a,,,129
asel,a,,,153
asel,a,,,156
asel,a,,,161
asel,a,,,164
asel,a,,,173
vsla
eslv
emodif,all,esys,101
```

```
!--all other rebars are in cylindrical system 110
asel,s,type,,type_2d_rebar
vsla
eslv
esel,u,esys,,100,101
emodif,all,esys,110

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Define real constants for rebars
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
mat_null=0

!slab
vrx=
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
*dim,rc,,20
vrx(1)=.0164,.0552,.0552,.0082,0    ,0    ,0
vry(1)=.0164,0    ,.0982,.0982,.1208,.0219,.1208
vrz(1)=0.   ,0.   ,0.   ,0.   ,.0634,.0368,.0368
rc(1)=100,101,102,103,104,105,106
*do,i,1,7
      r,rc(i),mat_srebar,vrx(i),0,0,mat_srebar,vry(i)
      rmore,90,0,mat_srebar,vrz(i),90,90
*enddo

!wall
vrx=
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
*dim,rc,,20
vrz(1)=.0368,.0368,.0368,.0368,.0368,.0368
vry(1)=.1002,.0601,.0752,.1002,.0601,.0219
rc(1)=201,202,203,204,205,206
*do,i,1,6
      r,rc(i),mat_null,0,0,0,mat_rebar,vry(i)
      rmore,90,0,mat_rebar,vrz(i),90,90
*enddo

!dome and haunch
vrx=
```

```
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
*dim,rc,,20
vry(1)=.0368,.0412,.0446,.0535,.0431,.0798,.0729,.2534,.0729
vrz(1)=.0368,.0368,.0368,.0368,.0654,.0982,.2062,.0736,.1590
rc(1)=300,301,302,303,304,305,306,307,308
*do,i,1,9
      r,rc(i),mat_null,0,0,0,mat_rebar,vry(i)
      rmore,90,0,mat_rebar,vrz(i),0,90
*enddo

!haunch core
vrx=
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
*dim,rc,,20

r,500,mat_rebar,.0013,0,0,mat_rebar,0.0088
rmore,45,0,mat_rebar,.032,0,90

r,501,mat_rebar,.0013,0,0,mat_rebar,0.0088
rmore,90,0,mat_rebar,.032,0,90

allsel


!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Assign real constants to 3D elements
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
*do,i,100,120
    asel,s,real,,i
    vsla
    eslv
    emodif,all,real,i
*enddo

*do,i,200,220
    asel,s,real,,i
    vsla
    eslv
    emodif,all,real,i
```

```
*enddo

*do,i,300,320
    asel,s,real,,i
    vsla
    eslv
    emodif,all,real,i
*enddo

*do,i,400,410
    asel,s,real,,i
    vsla
    eslv
    emodif,all,real,i
*enddo

*do,i,500,503
    asel,s,real,,i
    vsla
    eslv
    emodif,all,real,i
*enddo

allsel

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Define contact between soil and tank
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
et,21,170
et,22,173
r,21,,,10,.1
mp,mu,21,.3

asel,s,,,210
asel,a,,,230,240
asel,a,,,243
asel,a,,,256,266
asel,a,,,269,287
cm,tk_cnt_area,area
lsla
nsla,,1
esln
type,22
real,21
mat,21
esurf

asel,s,,,766,776
asel,a,,,783,794
```

```
asel,a,,,798,817
cm,soil_cnt_area,area
lsla
nsla,,1
esln
type,21
esurf

allsel
aclear,all

/pnum,real,1
/num,1

csys,110
allsel
nrotat,all
csys,0
eplot

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     set up AOR loadings and solve
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
slice_load_bx
allsel
finish
/filname,sst_bx_slice
/title,SST-BX slice model
/solu
nlgeom,on
nsubst,10,100,5
save
solve
```

parm_bx.mac

```
!--Define parameters for SST-BX tank
!--dimensions are in INCH and DEG
*afun,deg

t1=12  !tank wall thichness at bottom

dm_r1=96*12+3  !inch, radius of outer inboard dome surface
dm_r2=95*12    !inch, radius of inner inboard dome surface
dm_r3=67*12     !inch, radius of outer outboard dome surface
dm_r4=60*12     !inch, radius of inner outboard dome surface

hnch_r1=10*12     !inch, big haunch radius
hnch_r2=24

bot_r1=48
bot_r2=50

depth=8.83*12
soil_r=80*12
soil_h=40*12

!--following are dimensions for essential kp to
!  create the tank, starting from dome apex
r1=0
h1=0

r2=15*12+2+3/8
h2=14.5

r3=r2+13*12+7+1/8
h3=4*12+10.5

r4=r3+9*12+9.5
h4=8*12+8

r5=r4
h5=h4+23*12+3.75-20.75-4

r6=r5+24
h6=h5

r7=r6
h7=h4+23*12+3.75

r8=r7-24-26-5/16-31-13/16
h8=h7

r9=0
h9=33*12+1/8-1-1/8
```

```
r10=0
h10=h9-6

r11=r8
h11=h8-6

r12=r7-24-26-5/16
h12=h6+4

r13=r12
h13=h12-2

r19=0
h19=15

r18=15*12
h18=h19+14+5/16

r17=r18+18*12+4+5/8
h17=h18+6*12+1+3/16


r16=r17+3*12+10+7/8
h16=h17+(3*12+8)

r15=r16+3.5
h15=h16+12.25

r14=r15
h14=h15+71.25+71+26+1/16

!---Control Parameters for materials
crush_id=0  !=0, no crush capability, =1, with crush capability
usr_crp_id=0 !=0, no user creep; =1, with user creep

!---Parameters for materials
steel_ex=27.7e6   !elastic modulus [psi]
steel_prxy=0.3    !Poisson ratio
steel_alpx=6.38   !thermal expansion coefficient [microstrain/degree F]
steel_gamma=490   !unit weight [lbf/ft^3]
steel_kx=1        !thermal conductivity [BTU/hr/ft/degreeF]
steel_c=1         !specific heat [BTU/R-lbf/(in/sec^2)]
steel_alpx=steel_alpx*1e-6          !in/in/F
steel_dens=steel_gamma/1728/386     !lb-sec^2/in^4
steel_kx=steel_kx/3600/12           !BTU/sec-in-degreeF
steel_yield=36000 !yield strength [psi]


!----- Structural Concrete
conc_ex=3.1e6     !elastic modulus [psi]
```

```
conc_prxy=0.2      !Poisson ratio
conc_alpx=6.38     !thermal expansion coefficient [microstrain/degree F]
conc_gamma=150     !unit weight [lbf/ft^3]
conc_kx=1          !thermal conductivity [BTU/hr/ft/degreeF]
conc_c=1           !specific heat [BTU/R-lbf/(in/sec^2)]
conc_alpx=conc_alpx*1e-6            !in/in/F
conc_dens=conc_gamma/1728/386 !lb-sec^2/in^4
conc_kx=conc_kx/3600/12       !BTU/sec-in-degreeF
conc_open=0.1            !shear transfer coefficient for open crack
conc_closed=0.98  !shear transfer coefficient for closed crack
conc_crush=3000   !uniaxial crushing stress [psi]
conc_crack=0.1*conc_crush     !tensile cracking stress [psi]

c1=.1936    !creep coefficients per Tab 11 of RPP-13990
c2=.28
c3=.375
c4=.348
c5=.069
c6=226.09
c7=-0.00429
c8=147.52
c9=-.367
c10=-309.26
c11=-.044

!--bottom soil
bsoil_ex=20e3      !elastic modulus [psi]
bsoil_prxy=0.27    !Poisson ratio
bsoil_alpx=0             !thermal expansion coefficient [me/F]
bsoil_gamma=125    !unit weight [lbf/ft^3]
bsoil_kx=1         !thermal conductivity [BTU/hr/ft/F]
bsoil_c=1          !specific heat [BTU/R/(lbf-sec^2/in)]
bsoil_cohesion=0   !drucker-prager constant (assume small number) [psi]
bsoil_friction=35.4!internal friction angle [deg]
bsoil_dilat=35.4   !dilatancy angle [deg]
bsoil_alpx=bsoil_alpx*1e-6    !in/in/F
bsoil_dens=bsoil_gamma/1728/386     !lb-sec^2/in^4
bsoil_kx=bsoil_kx/3600/12           !BTU/sec-in-degreeF

!--mid soil
msoil_ex=13e3
msoil_prxy=0.27
msoil_dens=125/1728/386
msoil_cohesion=0   !drucker-prager constant (assume small number) [psi]
msoil_friction=35.4
msoil_dilat=35.4   !dilatancy angle [deg]


!-top soil
tsoil_ex=7e3
tsoil_prxy=0.27
```

```
tsoil_dens=125/1728/386
tsoil_cohesion=0  !drucker-prager constant (assume small number) [psi]
tsoil_friction=35.4
tsoil_dilat=35.4  !dilatancy angle [deg]


!----rebar steel
rebar_ex=27.7e6          !elastic modulus [psi]
rebar_prxy=0.3           !Poisson ratio
rebar_alpx=6.38*1e-6     !thermal expansion coefficient
[microstrain/degree F]
rebar_gamma=490   !unit weight [lbf/ft^3]
rebar_kx=1        !thermal conductivity [BTU/hr/ft/degreeF]
rebar_c=1         !specific heat [BTU/R-lbf/(in/sec^2)]
rebar_yield=60000 !yield strength [psi]
rebar_tan=0       !rebar tangent modulus [psi]
rebar_dens=rebar_gamma/1728/386  !lb-sec^2/in^4
rebar_kx=rebar_kx/3600/12  !BTU/sec-in-F


!---Slab rbar steel
srebar_ex=27.7e6  !elastic modulus [psi]
srebar_prxy=0.3          !Poisson ratio
srebar_alpx=6.38*1e-6    !thermal expansion coefficient
[microstrain/degree F]
srebar_gamma=490  !unit weight [lbf/ft^3]
srebar_kx=1       !thermal conductivity [BTU/hr/ft/degreeF]
srebar_c=1        !specific heat [BTU/R-lbf/(in/sec^2)]
srebar_yield=40000       !yield strength [psi]
srebar_tan=0             !rebar tangent modulus [psi]
srebar_dens=srebar_gamma/1728/386  !lb-sec^2/in^4
srebar_kx=srebar_kx/3600/12  !BTU/sec-in-F

!---Element size control
liner_size=5
tank_size=5
soil_esize=30
cload_div=10
slice_ang=3

!---liner thickness
liner_t=3/8

!--Load
p_uniform=40/144
ff=200000
cload_l=10*12

vac_pres=-0.217  !-6" w.g. vacuum
```

slice_load_bx.mac

```
finish
/prep7
!--set BCs
wpcsys,-1,0
kwpave,1
csys,4
asel,s,loc,x,soil_r
lsla
nsla,,1
d,all,ux,0

allsel
asel,s,loc,y,-h9-soil_h
lsla
nsll,,1
d,all,uz,0

allsel
nsel,s,loc,x,0
d,all,ux,0

csys,110
asel,s,loc,y,-.1,.1
lsla
nsla,,1
d,all,uy,0
asel,s,loc,y,slice_ang-.1,slice_ang+.1
lsla
nsla,,1
d,all,uy,0

wpcsys,-1,0
kwpave,1
csys,4
asel,s,loc,y,depth-.1,depth+.1
lsla
nsla,,1
esln
sf,all,pres,p_uniform

lsla
ksll
ksel,r,loc,x,-.1,cload_l+.5
lslk,,1
asll,,1
p_cload=ff/(3.14159*cload_l**2)
nsla,,1
sf,all,pres,p_cload+p_uniform
allsel
```

```
acel,,386

!Apply -6" w.g. to dome
esel,s,mat,,mat_conc
vsle
aslv
asel,r,ext
csys,110
asel,u,loc,y,-.1,.1
asel,u,loc,y,slice_ang-.1,slice_ang+.1
cmsel,u,tk_cnt_area
lsla

nsla,,1
sf,all,pres,vac_pres

allsel
```

pst_bx_slice.mac

```
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     post processing macro to obtain the section
!     force forces and moments
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
finish
/clear
/filname,sst_bx_slice
/prep7
resume
allsel
*afun,deg

/post1
set,last

cont_id=1
*if,cont_id,eq,1,then
!-----Displacement contours
allsel
plnsol,u,sum
plpng

esel,s,mat,,mat_conc
/rep
plpng

/dscale
allsel
/pnum,mat,1
/num,1
/edge,,1
pldisp,2
plpng

esel,s,mat,,mat_conc
/rep
plpng

allsel
/edge
/dscale,,1
plnsol,s,eqv
plpng

esel,s,mat,,mat_conc
/rep
plpng
```

```
/gresume,smisc_plt,plt
esel,s,mat,,mat_conc
/dscale,,1
/edge
plesol,smisc,2
plpng

plesol,smisc,4
plpng

plesol,smisc,6
plpng

*endif

!--------------Section force/moment path plots
csys,110
esel,s,mat,,2
vsle
aslv
asel,r,loc,y,-slice_ang-.1,-slice_ang+.1
cm,a_tank2,area

!--------------------SECTION FORCE/MOMENT

*dim,path_nd,,1000      !path node definition
*dim,path_fa,,1000      !axial force
*dim,path_ft,,1000      !transverse force
*dim,path_mz,,1000      !moment
*dim,path_fh,,1000

csys,110
pstart=0  !starting point of consequent path points

!=========================dome region
lsel,s,,,1,2
lsel,a,,,4
lsel,a,,,34
lsel,a,,,257,261,4
lsel,a,,,287
lsel,a,,,308
lsel,a,,,311
lsel,a,,,363
lsel,a,,,379
nsll,,1
cm,nd_out,node

lsel,s,,,28
lsel,a,,,38
lsel,a,,,50
```

```
lsel,a,,,88
lsel,a,,,116
lsel,a,,,309
lsel,a,,,345
lsel,a,,,353
lsel,a,,,376
lsel,a,,,378
lsel,a,,,382
nsll,,1
cm,nd_in,node

!--unselect end nodes
cmsel,s,nd_out
*get,x_min,node,,mnloc,x
nsel,u,loc,x,x_min-.1,x_min+.1
cm,nd_out,node

cmsel,s,nd_in
*get,x_min,node,,mnloc,x
nsel,u,loc,x,x_min-.1,x_min+.1
cm,nd_in,node


!--reorder nodes according x-coord.
cmsel,s,nd_out
*get,out_num,node,,count
*dim,nodeout,,out_num
*do,i,1,out_num
    cmsel,s,nd_out
    *get,x_min,node,,mnloc,x
    nsel,r,loc,x,x_min-.1,x_min+.1
    *get,ndnum,node,,num,min
    nodeout(i)=ndnum
    cmsel,s,nd_out
    nsel,u,,,ndnum
    cm,nd_out,node
*enddo

cmsel,s,nd_in
*get,in_num,node,,count
*dim,nodein,,in_num
*do,i,1,in_num
    cmsel,s,nd_in
    *get,x_min,node,,mnloc,x
    nsel,r,loc,x,x_min-.1,x_min+.1
    *get,ndnum,node,,num,min
    nodein(i)=ndnum
    cmsel,s,nd_in
    nsel,u,,,ndnum
    cm,nd_in,node
*enddo
```

```
cmsel,s,a_tank
wpcsys,-1,0
kwpave,263
csys,4
asel,r,loc,x,0,-99999
asel,r,loc,y,-100,9999
asel,a,,,31
asel,a,,,39
cm,dome_area,area
lsla
nsla,,1
cm,dome_nd,node

wpcsys,-1,0
csys,0

!--for line equation for each pair of in/out nodes
*do,ii,1,in_num
    nsel,s,,,nodeout(ii)
    nsel,a,,,nodein(ii)
    path_nd(pstart+ii)=nodein(ii)
    csys,0
    *get,x_out,node,nodeout(ii),loc,x
    *get,y_out,node,nodeout(ii),loc,y
    *get,x_in,node,nodein(ii),loc,x
    *get,y_in,node,nodein(ii),loc,y

    nwpla,-1,nodeout(ii),nodein(ii)
    csys,4
    cmsel,s,dome_nd
    nsel,r,loc,y,-2,2
    cm,ntemp,node
    esln
    esel,r,mat,,2
    nsle
    nsel,r,loc,y,-1,99999
    esln,,1
    cm,etemp,elem
    cmsel,s,ntemp
    cmsel,s,etemp
    csys,0
    get_res_slice
    cmsel,s,ntemp
    ttt=sqrt((x_out-x_in)**2+(y_out-y_in)**2)
    get_hpfrc

    path_fa(pstart+ii)=unit_fsumy
    path_ft(pstart+ii)=unit_fsumx
    path_mz(pstart+ii)=-unit_mz
    path_fh(pstart+ii)=hp_f
```

```
*enddo

pstart=pstart+in_num

!==============Haunch and wall
lsel,s,,,25
lsel,a,,,82
lsel,a,,,123
lsel,a,,,133
lsel,a,,,253
lsel,a,,,259
lsel,a,,,281
lsel,a,,,298
lsel,a,,,301
lsel,a,,,315
lsel,a,,,326
lsel,a,,,406
nsll,,1
cm,nd_out,node

lsel,s,,,12,15
lsel,a,,,89
lsel,a,,,134
lsel,a,,,270
lsel,a,,,279
lsel,a,,,291,293,2
lsel,a,,,303
lsel,a,,,323
nsll,,1
cm,nd_in,node

cmsel,s,a_tank
wpcsys,-1,0

kwpave,103
cmsel,u,dome_area
csys,4
asel,r,loc,y,0,9999
asel,r,loc,x,0,-99999
cm,wall_area,area
lsla
nsla,,1
cm,wall_nd,node

csys,0
!--unselect end nodes
cmsel,s,nd_out
*get,y_max,node,,mxloc,y
```

```
nsel,u,loc,y,y_max-.1,y_max+.1
cm,nd_out,node

cmsel,s,nd_in
*get,y_max,node,,mxloc,y
nsel,u,loc,y,y_max-.1,y_max+.1
cm,nd_in,node

nodeout(1)=
nodein(1)=

!--reorder nodes according y-coord.
cmsel,s,nd_out
*get,out_num,node,,count
*dim,nodeout,,out_num
*do,i,1,out_num
      cmsel,s,nd_out

      *get,y_max,node,,mxloc,y
      nsel,r,loc,y,y_max-.1,y_max+.1
      *get,ndnum,node,,num,min
      nodeout(i)=ndnum
      cmsel,s,nd_out
      nsel,u,,,ndnum
      cm,nd_out,node
*enddo

cmsel,s,nd_in
*get,in_num,node,,count
*dim,nodein,,in_num
*do,i,1,in_num
    cmsel,s,nd_in
    *get,y_max,node,,mxloc,y
    nsel,r,loc,y,y_max-.1,y_max+.1
    *get,ndnum,node,,num,min
    nodein(i)=ndnum
    cmsel,s,nd_in
    nsel,u,,,ndnum
    cm,nd_in,node
*enddo


!--line equation for each pair of in/out nodes
*do,ii,1,in_num
    nsel,s,,,nodeout(ii)
    nsel,a,,,nodein(ii)
    path_nd(pstart+ii)=nodein(ii)
    csys,0
    *get,x_out,node,nodeout(ii),loc,x
    *get,y_out,node,nodeout(ii),loc,y
    *get,x_in,node,nodein(ii),loc,x
```

```
    *get,y_in,node,nodein(ii),loc,y

    nwpla,-1,nodeout(ii),nodein(ii)
    csys,4
    cmsel,s,wall_nd
    nsel,r,loc,y,-1,1
    cm,ntemp,node
    esln
    esel,r,mat,,2
    nsle
    nsel,r,loc,y,-1,99999
    esln,,1
    cm,etemp,elem
    cmsel,s,ntemp
    cmsel,s,etemp
    csys,0
    get_res_slice

    cmsel,s,ntemp
    ttt=sqrt((x_out-x_in)**2+(y_out-y_in)**2)
    get_hpfrc

    path_fa(pstart+ii)=unit_fsumy
    path_ft(pstart+ii)=unit_fsumx
    path_mz(pstart+ii)=-unit_mz
    path_fh(pstart+ii)=hp_f

*enddo

pstart=pstart+in_num

!==========================slab region
lsel,s,,,8
lsel,a,,,247
lsel,a,,,396
nsll,,1
cm,nd_out,node

lsel,s,,,10
lsel,a,,,139
lsel,a,,,166
nsll,,1
cm,nd_in,node

csys,110
!--unselect end nodes
cmsel,s,nd_out
*get,x_max,node,,mxloc,x
nsel,u,loc,x,x_max-.1,x_max+.1
cm,nd_out,node
```

```
cmsel,s,nd_in
*get,x_max,node,,mxloc,x
nsel,u,loc,x,x_max-.1,x_max+.1
cm,nd_in,node

nodeout(1)=
nodein(1)=

!--reorder nodes according x-coord.
cmsel,s,nd_out
*get,out_num,node,,count
*dim,nodeout,,out_num
*do,i,1,out_num
    cmsel,s,nd_out
    *get,x_max,node,,mxloc,x
    nsel,r,loc,x,x_max-.1,x_max+.1
    *get,ndnum,node,,num,min
    nodeout(i)=ndnum
    cmsel,s,nd_out
    nsel,u,,,ndnum
    cm,nd_out,node
*enddo

cmsel,s,nd_in
*get,in_num,node,,count
*dim,nodein,,in_num
*do,i,1,in_num
    cmsel,s,nd_in
    *get,x_max,node,,mxloc,x
    nsel,r,loc,x,x_max-.1,x_max+.1
    *get,ndnum,node,,num,min
    nodein(i)=ndnum
    cmsel,s,nd_in
    nsel,u,,,ndnum
    cm,nd_in,node
*enddo

cmsel,s,a_tank
cmsel,u,dome_area
cmsel,u,wall_area
cm,slab_area,area
lsla
nsla,,1
cm,slab_nd,node

!--for line equation for each pair of in/out nodes
*do,ii,1, in_num-1
    nsel,s,,,nodeout(ii)
    nsel,a,,,nodein(ii)
    path_nd(pstart+ii)=nodein(ii)
    csys,0
```

```
    *get,x_out,node,nodeout(ii),loc,x
    *get,y_out,node,nodeout(ii),loc,y
    *get,x_in,node,nodein(ii),loc,x
    *get,y_in,node,nodein(ii),loc,y

    *if,ii,ne,in_num,then
          *get,xplus_in,node,nodein(ii+1),loc,x
          *get,yplus_in,node,nodein(ii+1),loc,y
          ds=sqrt((xplus_in-x_in)**2+(yplus_in-y_in)**2)
    *endif

    nwpla,-1,nodeout(ii),nodein(ii)
    csys,4
    cmsel,s,slab_nd
    nsel,r,loc,y,-1,1
    cm,ntemp,node
    esln
    esel,r,mat,,2
    nsle
    nsel,r,loc,y,-1,99999
    esln,,1
    cm,etemp,elem
    cmsel,s,ntemp
    cmsel,s,etemp
    csys,0
    get_res_slice

    cmsel,s,ntemp
    ttt=sqrt((x_out-x_in)**2+(y_out-y_in)**2)
    get_hpfrc

    path_fa(pstart+ii)=unit_fsumy
    path_ft(pstart+ii)=unit_fsumx
    path_mz(pstart+ii)=-unit_mz
    path_fh(pstart+ii)=hp_f

*enddo

pstart=pstart+in_num-1

rsys,0

/gresume,path_bx,plt
axial_path
plpng

shear_path
plpng

hoop_path
plpng
```

```
moment_path
plpng

!----Output path data to file
/sys,del path_bx.dat
*dim,pl,,pstart
ss=0
*do,i,1,pstart
     *get,path_x,path,,point,i,x
     *get,path_y,path,,point,i,y
     *if,i,gt,1,then
         ss=ss+sqrt((path_x-path_x0)**2+(path_y-path_y0)**2)
     *endif
     pl(i)=ss
     path_x0=path_x
     path_y0=path_y
*enddo

i=1
/output,path_ax,dat,,
*vwrite,pl(i),path_fa(i),path_ft(i),path_fh(i),path_mz(i)
(5e12.4)
/output
```

get_res_slice.mac

```
cm,etemp,elem
cm,ntemp,node
*get,nelem,elem,,count
*get,nnode,node,,count

xx(1)=
yy(1)=
zz(1)=
ffx(1)=
ffy(1)=
ffz(1)=

*dim,xx,,nnode
*dim,yy,,nnode
*dim,zz,,nnode
*dim,ffx,,nnode
*dim,ffy,,nnode
*dim,ffz,,nnode

xmean=0
ymean=0
zmean=0

fsumx=0
fsumy=0
fsumz=0

cm,nn0,node
csys,0
*do,i,1,nnode
      *get,inode,node,,num,min
      nsel,s,,,inode
      xx(i)=nx(inode)
      yy(i)=ny(inode)
      zz(i)=nz(inode)
      xmean=xmean+xx(i)
      ymean=ymean+yy(i)
      zmean=zmean+zz(i)
      cmsel,s,nn0
      nsel,u,,,inode
      cm,nn0,node
*enddo

xmean=xmean/nnode
ymean=ymean/nnode
zmean=zmean/nnode

cmsel,s,ntemp
cmsel,s,etemp
```

```
spoint,,xmean,ymean,zmean

rsys,4
fsum,rsys

*get,fsumx,fsum,fx
*get,fsumy,fsum,fy
*get,fsumz,fsum,fz
*get,mmzz,fsum,mz


fsumx=fsumx/1000     !kip
fsumy=fsumy/1000     !kip
fsumz=fsumz/1000
mmzz=mmzz/1000       !kip-in

fct=3/360

arc_length=abs(3.14159*xmean*2)*fct

unit_fsumx=2*fsumx/arc_length*12 ! kip/ft
unit_fsumy=2*fsumy/arc_length*12 ! kip/ft
unit_mz=2*mmzz/arc_length*12     ! kip-in/ft
```

get_hpfrc.mac

```
*get,nnode,node,,count

csys,0

hp_f=0
sz_sum=0
nn=0
*do,i,1,nnode
      ndnxt=ndnext(nn)
      nsel,s,,,ndnxt
        esln
        esel,r,mat,,mat_conc
        cm,etemp,elem
        *get,s_z,node,ndnxt,s,z
        sz_sum=sz_sum+s_z
        cmsel,s,ntemp
        nn=ndnxt
*enddo

sz_sum=sz_sum/nnode

hp_f=sz_sum*ttt/1000*12  !kip/ft
```

axial_path.mac

```
!=======Define path
allsel
PADEL,ALL
path,in_surf,pstart,,1
*do,i,1,pstart
       ppath,i,path_nd(i)
       dnsol,path_nd(i),u,x,path_fa(i)
*enddo

allsel
PDEF,axial,u,x,AVG
/PBC,PATH, ,0


PLPAGM,axial,1000,Blank
/title,Axial Force (kip/ft)
/rep
```

shear_path.mac

```
!=======Define path
allsel
rsys,0
PADEL,ALL
path,in_surf,pstart,,1
*do,i,1,pstart
       ppath,i,path_nd(i)
       dnsol,path_nd(i),u,x,path_ft(i)
*enddo

allsel
PDEF,shear,u,x,AVG
/PBC,PATH, ,0


PLPAGM,shear,1000,Blank
/title,Shear Force (kip/ft)
/rep
```

hoop_path.mac

```
!=======Define path
allsel
PADEL,ALL
path,in_surf,pstart,,1
*do,i,1,pstart
       ppath,i,path_nd(i)
       dnsol,path_nd(i),u,x,path_fh(i)
*enddo

allsel
PDEF,hoop,u,x,AVG
/PBC,PATH, ,0


PLPAGM,hoop,1000,Blank
/title,Hoop Force (kip/ft)
/rep
```

moment_path.mac

```
!=======Define path
allsel
PADEL,ALL
path,in_surf,pstart,,1
*do,i,1,pstart
       ppath,i,path_nd(i)
       dnsol,path_nd(i),u,x,path_mz(i)
*enddo

allsel
PDEF,moment,u,x,AVG
/PBC,PATH, ,0


PLPAGM,moment,1000,Blank
/title,Moment (kip-in/ft)
/rep
```

plpng.mac

```
/SHOW,PNG
PNGR,COMP,1,-1
PNGR,ORIENT,HORIZ
PNGR,COLOR,2
PNGR,TMOD,1
/GFILE,600,
!*
/CMAP,_TEMPCMAP_,CMP,,SAVE
/RGB,INDEX,100,100,100,0
/RGB,INDEX,0,0,0,15
/REPLOT
/CMAP,_TEMPCMAP_,CMP
/DELETE,_TEMPCMAP_,CMP
/SHOW,CLOSE
/DEVICE,VECTOR,0
```

path_bx.plt

```
/NOPR
/RESET
/DEVICE,VECT,OFF
! General Graphics Settings
/NUM,  1
/PLOP,INFO, 3
/TRIAD,RTOP
/GTHIC,CURV,  2
/GROPT,CGRI,ON
/GROPT,CURL,  1
/PNUM,REAL, 1
/TRLCY,ON
/TXTRE,ON
/COL, PBAK,0, 1,  4
! Window Settings
/VIEW,1,  0.0000    ,  0.0000    ,  1.0000
/FOC, 1,  226.07    , -241.91    , 0.50000
/DIST,1,  282.66
/ANG, 1,-0.90000    ,ZS
/TYPE,1, 6
/EDG, 1, 0,  45.000
/CONT,1,  9,AUTO
/DSCA,1,  1.0000
/GO
```

smisc_plt.plt

```
/NOPR
/RESET
/DEVICE,VECT,OFF
! General Graphics Settings
/NUM,  1
/PLOP,INFO, 3
/TRIAD,RTOP
/GTHIC,CURV,  2
/GROPT,CURL,  1
/PNUM,REAL, 1
/TRLCY,ON
/TXTRE,ON
/COL, PBAK,0, 1,  4
! Window Settings
/VIEW,1,  0.0000    ,  0.0000    ,  1.0000
/FOC, 1,  224.48    , -220.38    , 0.50000
/DIST,1,  265.76
/TYPE,1, 6
/EDG, 1, 0,  45.000
/CONT,1,  9,AUTO
/DSCA,1,  1.0000
/GO
```