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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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				Parametric Model for Tank				
				SST-A				

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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-A

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Abstract: This document documents the ANSYS slice parametric model for single-shell tank A 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-A

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

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JLR The Engineering Solutions Company

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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-13995, Rev. 0, Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-A

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-13995, Rev. 0, Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-A

Author: Xianghong Li / Jim Radochia
JLR The Engineering Solutions Company

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

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

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

ERRATA

ANSYS Macro	Tracking #	Issue Description	Recommended Action
Parm_a.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_s.mac and Sst_s_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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1.0 OBJECTIVE/PURPOSE

The purpose of this calculation is to develop a parametric model for the single shell tank (SST) A, and provide a sample analysis of the SST-S tank based on analysis of record (AOR) loads. The SST-A 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-A tanks at the Hanford site.

2.0 METHODS OF ANALYSIS

1. A 3-degree slice 3D model of the SST-A tanks was first developed using the ANSYS Parametric Design Language (APDL) in ANSYS 7.0, a general purpose finite element analysis program [Ref_1]. Compared with the linear model reported in RPP-13997 [Ref_5], 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-A 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-A tank is provided in drawing H-2-55911 [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 8.45 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 [Ref_2]

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 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 the rebar volume ratio, the average radius was used during the calculation of the real constants for the radial 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-A tank include a uniform pressure load of 40 lbf/ft² on the soil surface and a concentrated load of 200 kip 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-A - Steel Reinforcement Ratios for Slab - Ref H-2-55912											100
Description	Elevation (in)	Radius (in)	Top / Meridional Size	Spacing	Area Ratio	Volume Ratio	Top/ Circumferential Size	Spacing	Area Ratio	Volume Ratio	Real Constant
Slab Center		0.0									
			5	12.0	0.0256	0.0256	5	12	0.0256	0.0256	100
Start of Thick. Trans.		372.5									
			8	10.0	0.0785	0.0785	5	12	0.0256	0.0256	101
End of Radial Rebars		506.5									
SST-A - Steel Reinforcement Ratios for Slab - Ref H-2-55912											100
Description	Elevation (in)	Radius (in)	Bottom / Meridional Size	Spacing (in)	Area Ratio	Volume Ratio	Bottom / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Slab Center		0.0									
Start of Bottom Rebar		378.6									
			8	10.0	0.0785	0.0785	5	12	0.0256	0.0256	102
End of Thick. Trans.		414.5									
			8	10.0	0.0785	0.0785	5	12	0.0256	0.0256	101
Slab Outside Radius		506.5									
SST-A - Steel Reinforcement Ratios for Slab - Ref H-2-55912											100
Description	Elevation (in)	Radius (in)	vertical region #1 (Exterior) /Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	vertical region #1 (Exterior) /Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Slab Outside Radius		506.5									
			0	0.0	0.0000	0.0000	0	0	0.0000	0.0000	103
Slab Outside Radius		506.5									
SST-AX - Steel Reinforcement Ratios for Slab - Ref H-2-44562											100
Description	Elevation (in)	Radius (in)	vertical region #2 /Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	vertical region #2/Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
		471.9									
			8	10.0	0.0785	0.0785	0	0	0.0000	0.0000	104
		471.9									
SST-A - Steel Reinforcement Ratios for Slab - Ref H-2-55912											100
Description	Elevation (in)	Radius (in)	vertical region #3 (Interior) /Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	vertical region #3 (Interior) /Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
		459.6									
			8	10.0	0.0785	0.0785	0	0	0.0000	0.0000	104
		459.6									

Table 3. Calculation of Steel Reinforcement Ratios for Wall

SST-A - Steel Reinforcement Ratios for Wall - Ref H-2-55912 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	390.8										
			8	20.0	0.0393	0.0393	8	8	0.0982	0.0982	201
	298.5										
			8	20.0	0.0393	0.0393	8	6	0.1309	0.1309	202
	256.5										
			8	20.0	0.0393	0.0393	8	4.75	0.1653	0.1653	203
	156.0										
			8	10.0	0.0785	0.0785	8	4.75	0.1653	0.1653	204
Top of Slab	0.0										

SST-A - Steel Reinforcement Ratios for Wall - Ref H-2-55912 200

Description	Elevation (in)	Radius (in)	Layer 2 / Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	Layer 2 / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Tangent Line	390.8										
	248.0										
			5	24	0.0128	0.0128	8	4.75	0.1653	0.1653	205
	190.0										
			5	24	0.0128	0.0128	8	8	0.0982	0.0982	206
Top of Slab	0.0										

SST-A - Steel Reinforcement Ratios for Wall - Ref H-2-55912 200

Description	Elevation (in)	Radius (in)	Exterior(layer 3) / Vertical Size	Spacing (in)	Area Ratio	Volume Ratio	Exterior (layer 4) / Circumferential Size	Spacing (in)	Area Ratio	Volume Ratio	Real Constant
Dome Tangent Line	390.8										
			8	20.0	0.0393	0.0393	8	8	0.0982	0.0982	201
	298.5										
			8	20.0	0.0393	0.0393	8	6	0.1309	0.1309	202
End of thick. Trans.	276.0										
			8	20.0	0.0393	0.0393	8	6	0.1309	0.1309	208
	256.5										
			8	20.0	0.0393	0.0393	8	4.75	0.1653	0.1653	207
Start of thick. Trans.	204.0										
			8	20.0	0.0393	0.0393	8	4.75	0.1653	0.1653	203
	156.0										
			8	10.0	0.0785	0.0785	8	4.75	0.1653	0.1653	204
Top of Slab	0.0										

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

SST-A - Steel Reinforcement Ratios for Dome and Haunch - Ref H-2-55913 300

Description	Elevation (in)	Radius (in)	External / Meridional 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	0.0736	6	12.0	0.0368	0.0736	300
			6	12.0	0.0368		6	12.0	0.0368		
		75.0									
			6	10.1	0.0437	0.0437	6	12.0	0.0368	0.0368	301
		120.0									
			6	7.8	0.0564	0.0564	6	12.0	0.0368	0.0368	302
		182.4									
			6	11.0	0.0403	0.0403	6	12.0	0.0368	0.0368	303
		240.0									
			6	7.6	0.0582	0.0582	6	12.0	0.0368	0.0368	304
Straight/curve joint		345.4									
			6	9.4	0.0471	0.0471	9	12.0	0.0833	0.0833	305
Haunch core 1 starts		378.0									
			6	5.2	0.0848	0.0848	9	8.4	0.1193	0.1193	306
Haunch core 2 starts		426.0									
			6	5.8	0.0767	0.0767	9	7.1	0.1403	0.1403	307
Outer Radius of Tank	66.4	462.9									
			6	6.0	0.0736	0.0736	11	6.1	0.2560	0.2560	308
Dome/Haunch Joint	0.0	462.9									

SST-A - Steel Reinforcement Ratios for Dome and Haunch - Ref H-2-55913 300

Description	Elevation (in)	Radius (in)	Internal / Meridional 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	0.0736	6	12.0	0.0368	0.0736	300
			6	12.0	0.0368		6	12.0	0.0368		
		75.0									
			6	10.1	0.0437	0.0437	6	12.0	0.0368	0.0368	301
		120.0									
			6	7.8	0.0564	0.0564	6	12.0	0.0368	0.0368	302
		182.4									
			6	11.0	0.0403	0.0403	6	12.0	0.0368	0.0368	303
		240.0									
			6	7.6	0.0582	0.0582	6	12.0	0.0368	0.0368	304
Straight/curve joint		345.4									
			6	9.4	0.0471	0.0471	9	12.0	0.0833	0.0833	305
Haunch core 1 starts		378.0									
			6	5.2	0.0848	0.0848	9	8.4	0.1193	0.1193	306
Haunch core 2 starts		426.0									
			6	5.8	0.0767	0.0767	9	10.7	0.0934	0.0934	309
Dome Tangent Line		462.9									

Table 5. Calculation of Steel Reinforcement Ratios for Haunch Core

SST-A - Steel Reinforcement Ratios for Haunch Interior - Ref H-2-55913 500

Description	Circumferential Size	Quantity	Bar area (in^2)	Area (in^2)	Volume Ratio	Diagonal Ties Size	Quantity	Bar area	Area (in^2)	Volume Ratio	Vertical Ties Size	Quantity	Bar area (in^2)	Area (in^2)	Volume Ratio	real constant
Up Haunch Interior																
	9	4	4.00	242.6	0.0165	0	0	0.00	0.00	0.00	0	0	0.00	0.00	0.00	501
Bottom Haunch Interior																
	11	25	39.04	1425	0.0274	5	7	2.15	1567	0.0014	5	7	2.1476	1143.00	0.0019	502

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_a_slice.mac	Main input creating parametric slice model for SST-A tank and getting solutions	parm_a.mac slice_load_a.mac
parm_a.mac	Set all parametric variables used to create the parametric model	NONE
slice_load_a.mac	Apply boundary conditions and AOR loads	NONE
pst_a_slice.mac	Calculate section forces/moments and generate path plots, output path data to path_s.dat file	get_res_slice.mac get_hpfrc.mac plpng.mac path_a.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_a.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	View setting for rebar stress plots	NONE

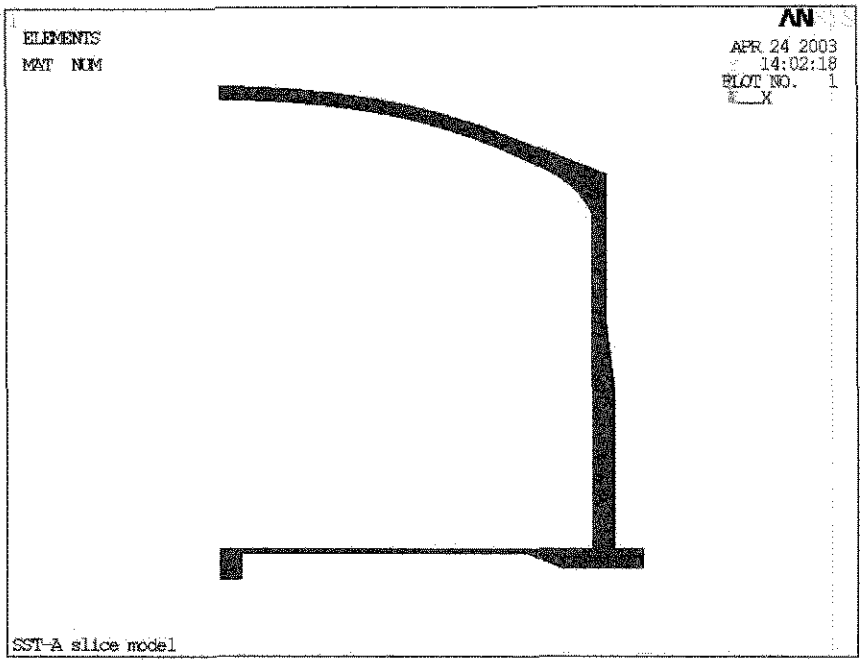

Figure 1. Geometry of SST-A Tank

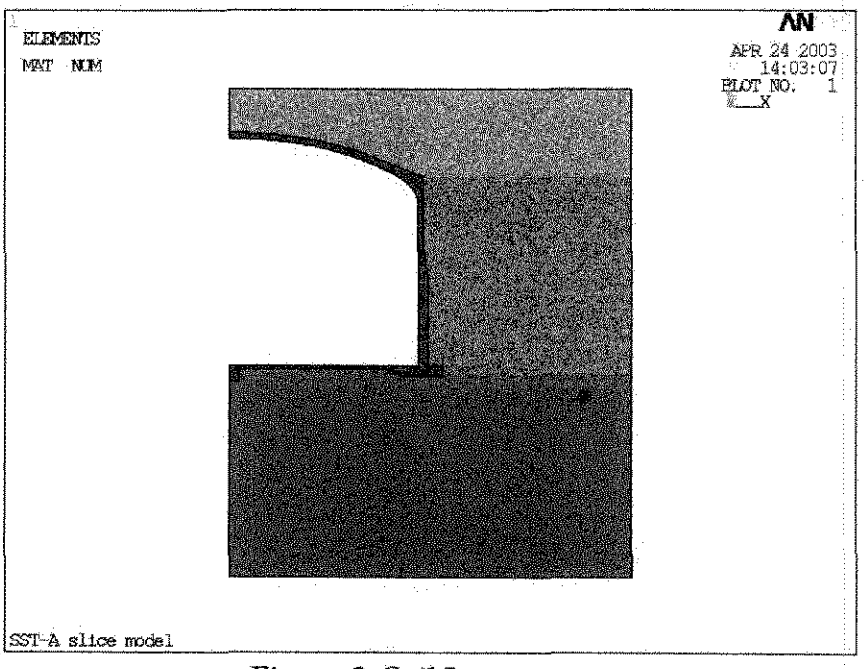

Figure 2. Soil Layers

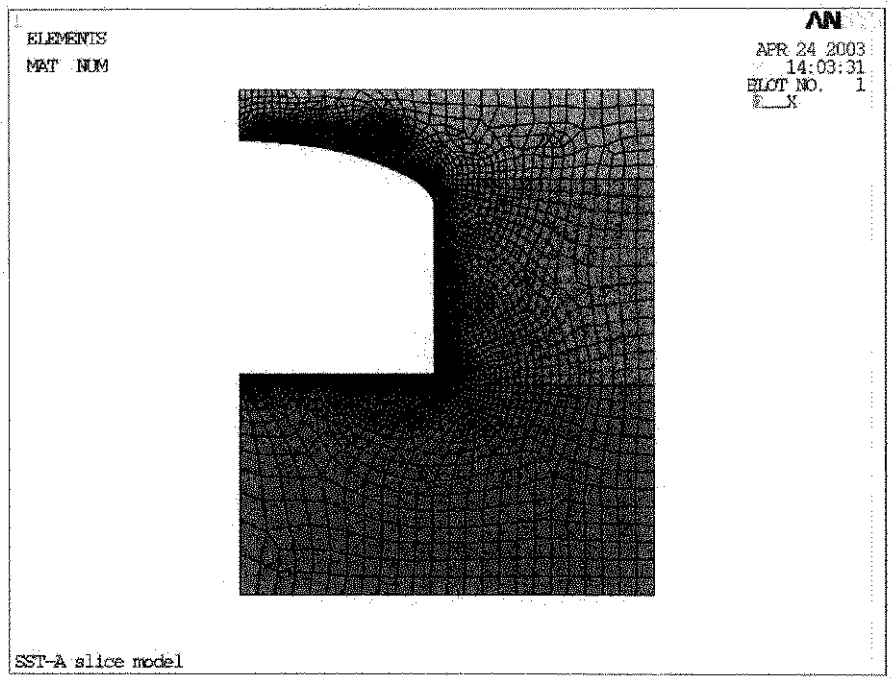

Figure 3. Finite element mesh, showing elements colored by material ID.

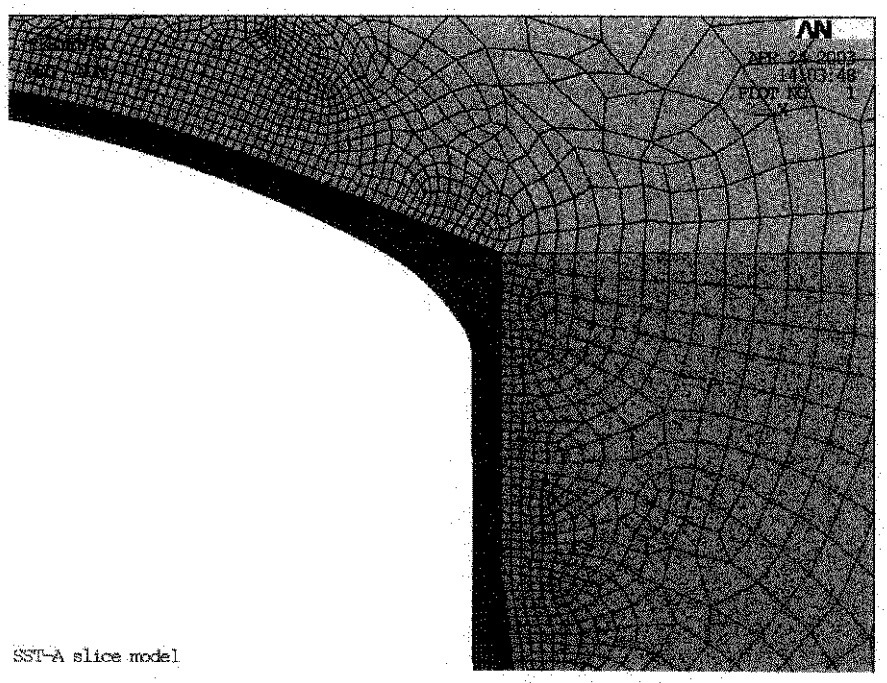

Figure 4. Close-up of finite element mesh.

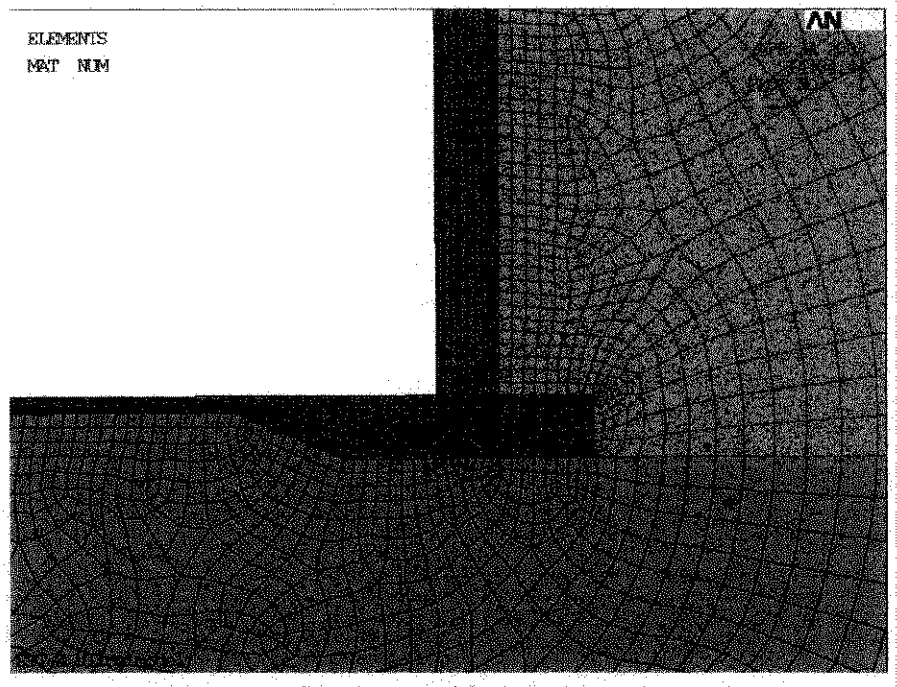

Figure 5. Close-up of finite element mesh.

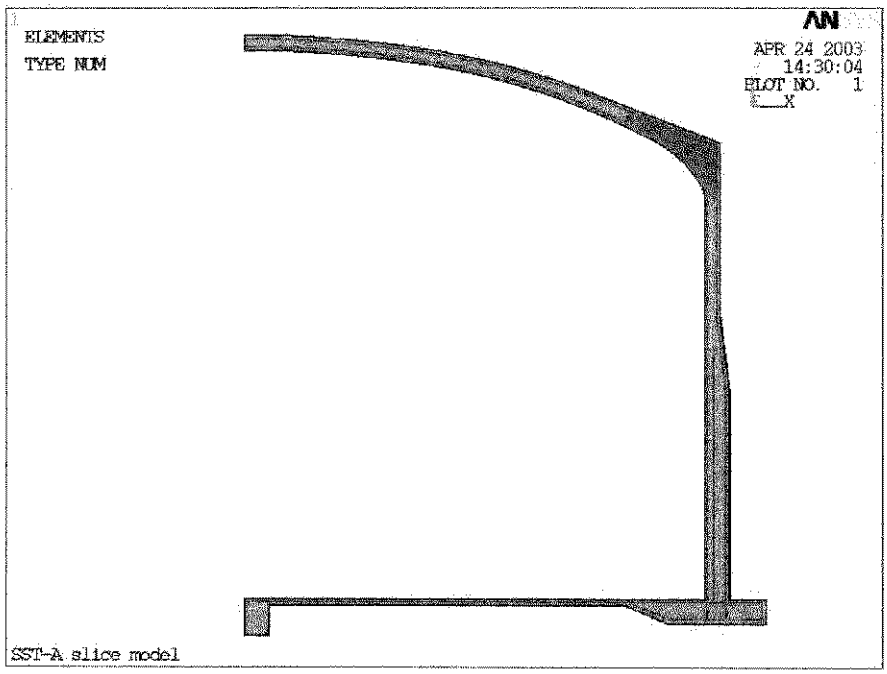

Figure 6. Rebar region (red colored area)

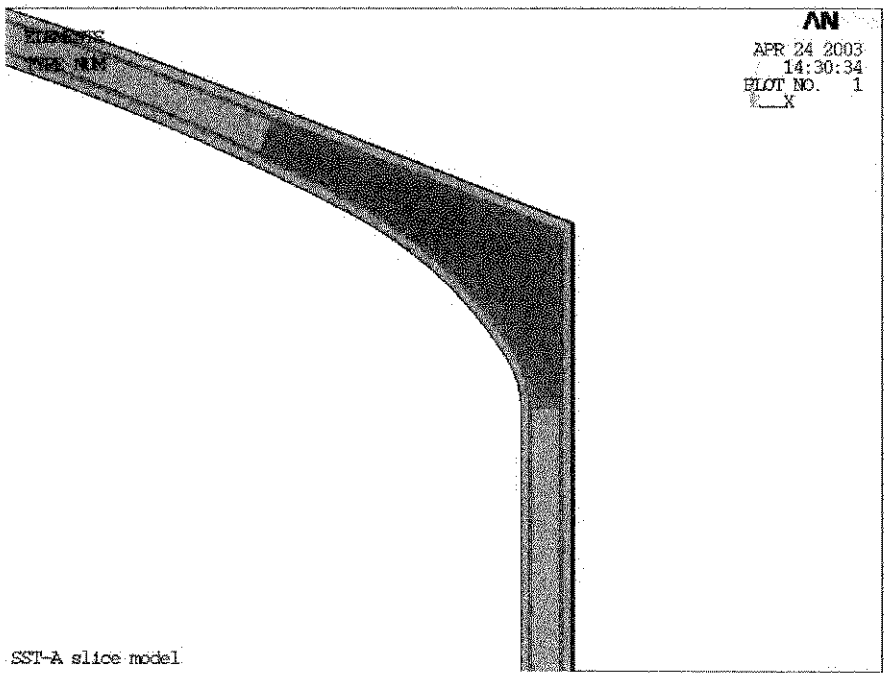

Figure 7. Close up of rebar region

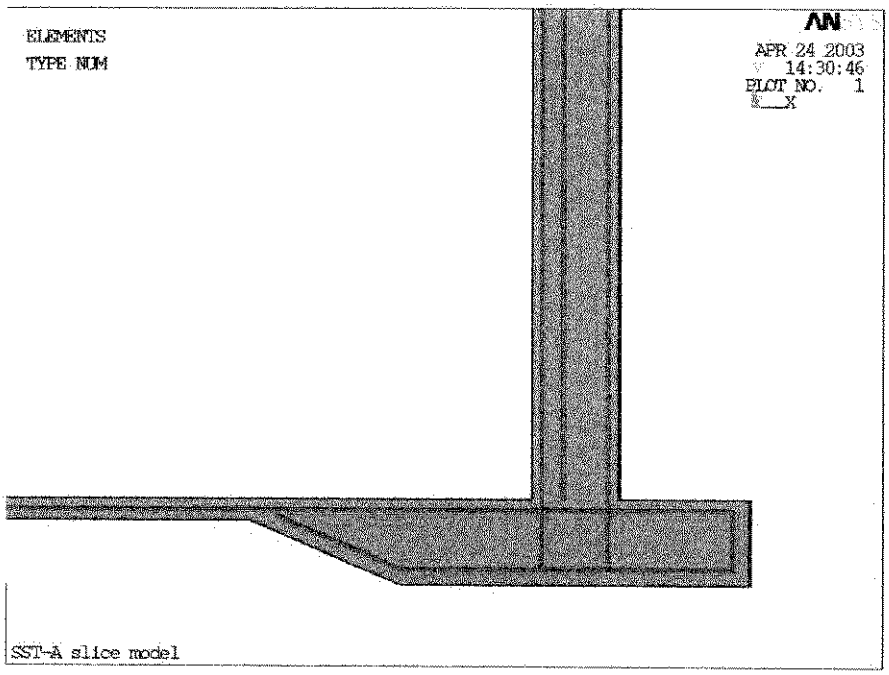

Figure 8. Close up of rebar region

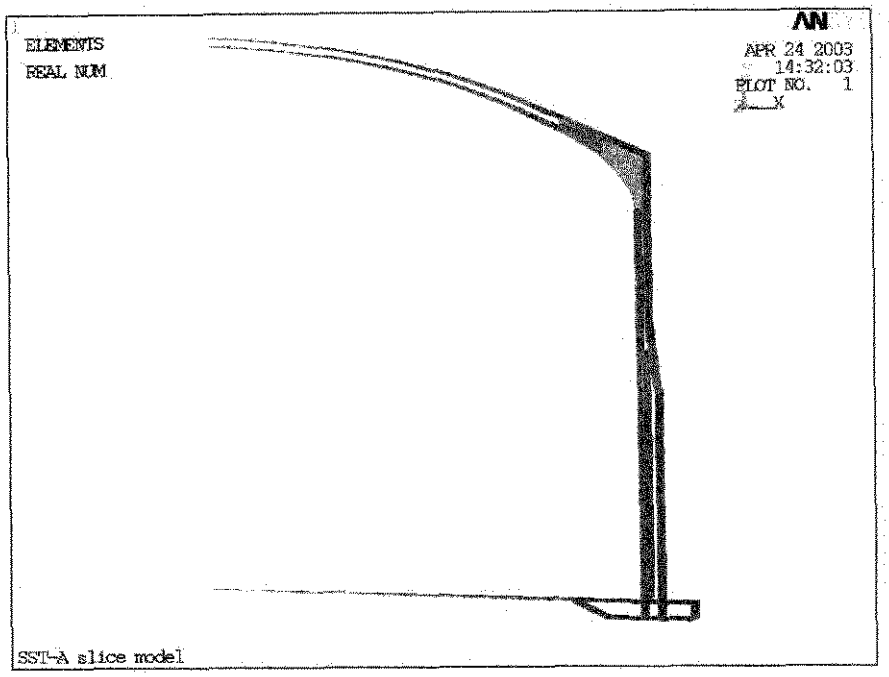

Figure 9. Rebar elements colored by real constants

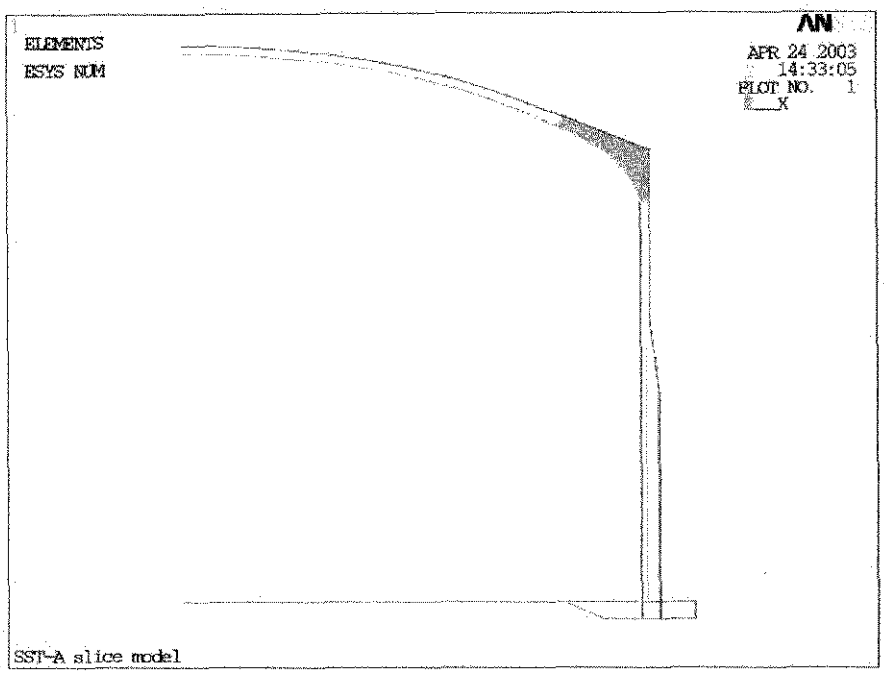

Figure 10. Rebar elements colored by element coordinate systems

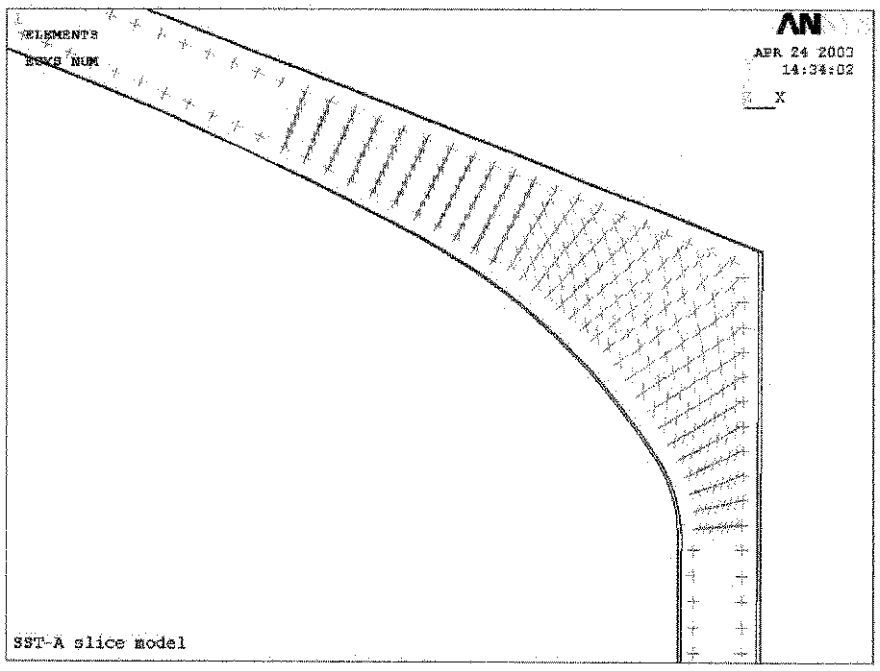

Figure 11. Rebar orientation at haunch core

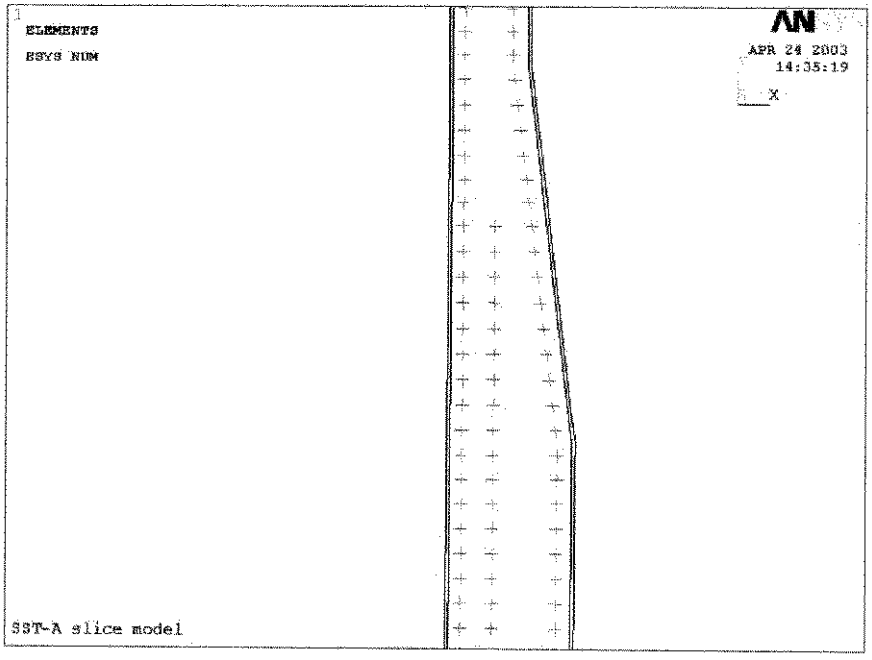

Figure 12. Rebar orientation at wall

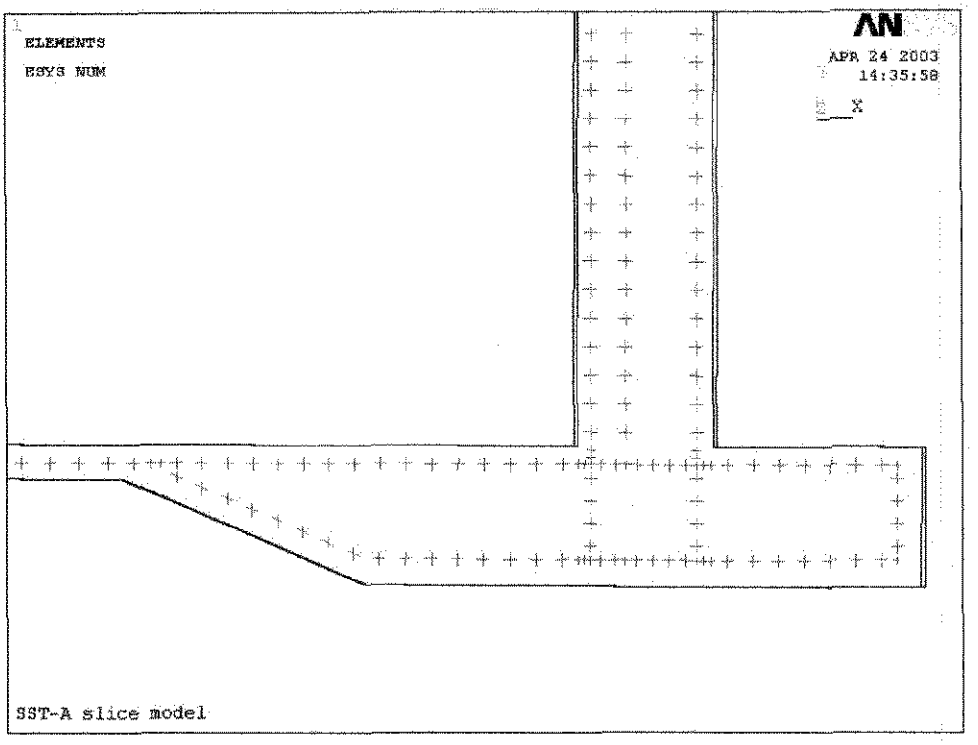

Figure 13. Rebar orientation at wall/slab joint

4.0 RESULTS

The solution can be obtained by running the master input macro **sst_a_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 2.3 inches, and this occurs at grade far away from the tank. The peak tank displacement is 1.6 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 2.4 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 487psi at the haunch region, and the minimum hoop stress is -1006 psi at the wall/slab joint. 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_a_slice.mac**. In order for **pst_a_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 wall/slab joint sees the most severe loading, with maximum axial force of about 98 kip/ft, maximum shear force of 50 kip/ft, and maximum moment of 1876 kip-in/ft. Maximum hoop force of 103 kip/ft occurs at the haunch region.

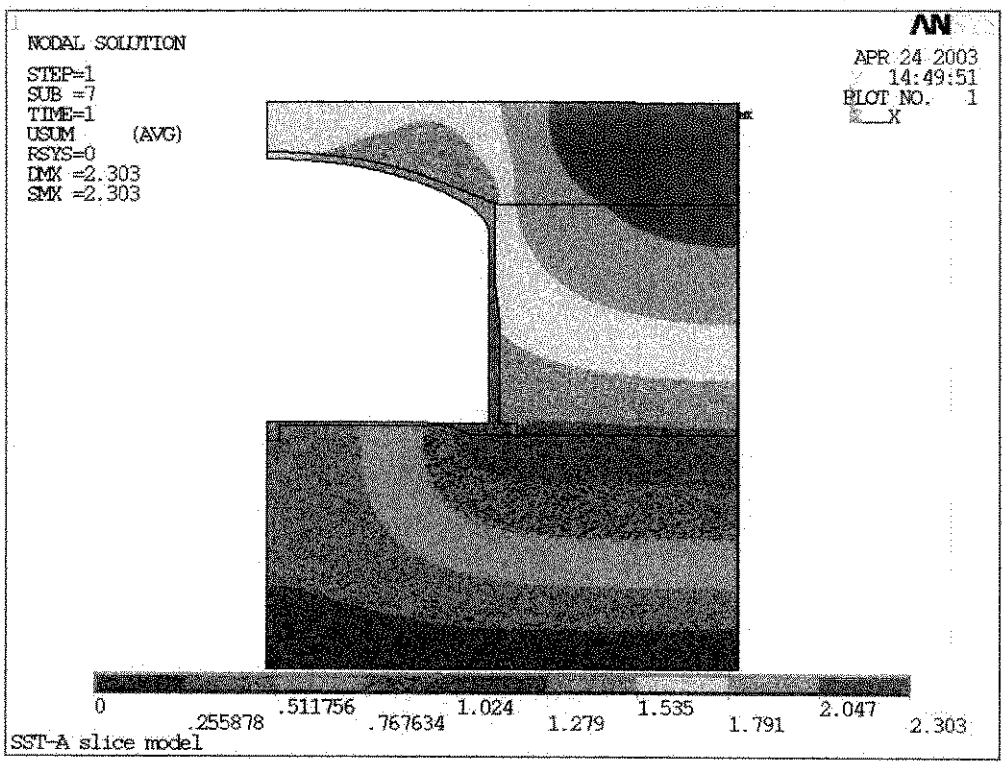

Figure 14. Total displacement contour of soil and tank

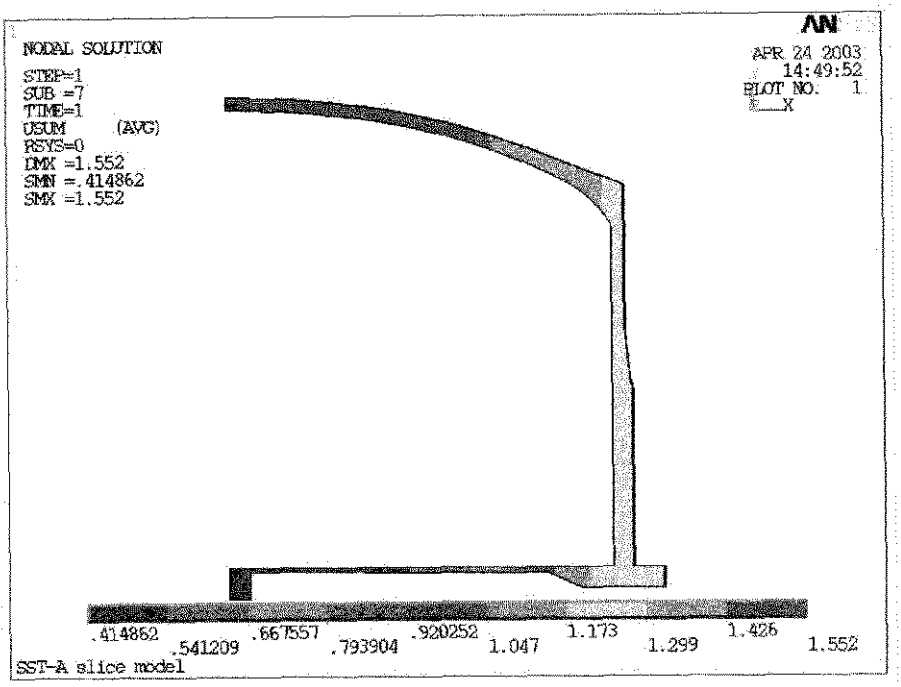

Figure 15. Total displacement contour of tank

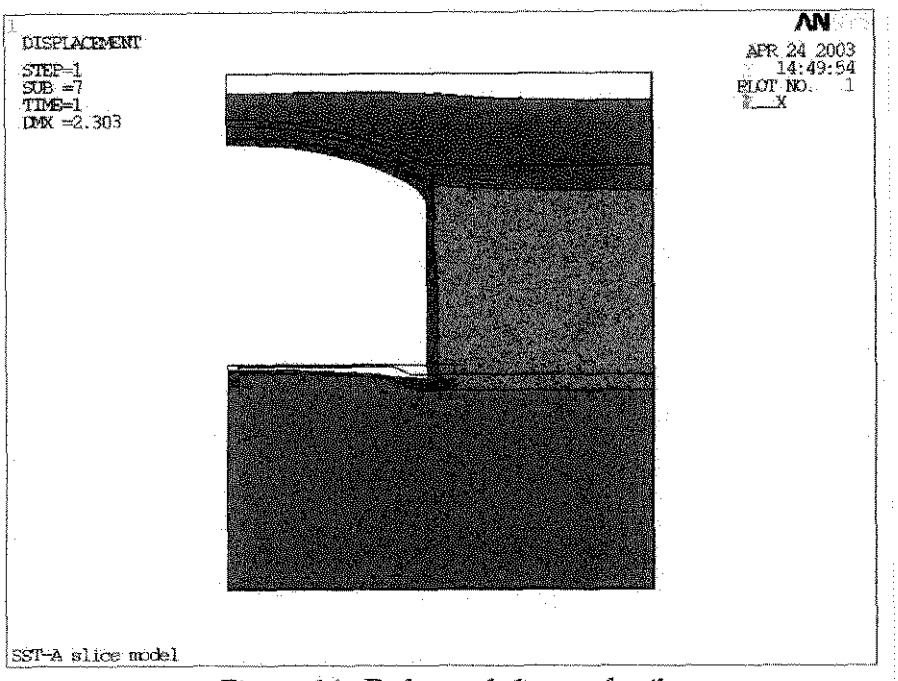

Figure 16. Deformed shape of soil

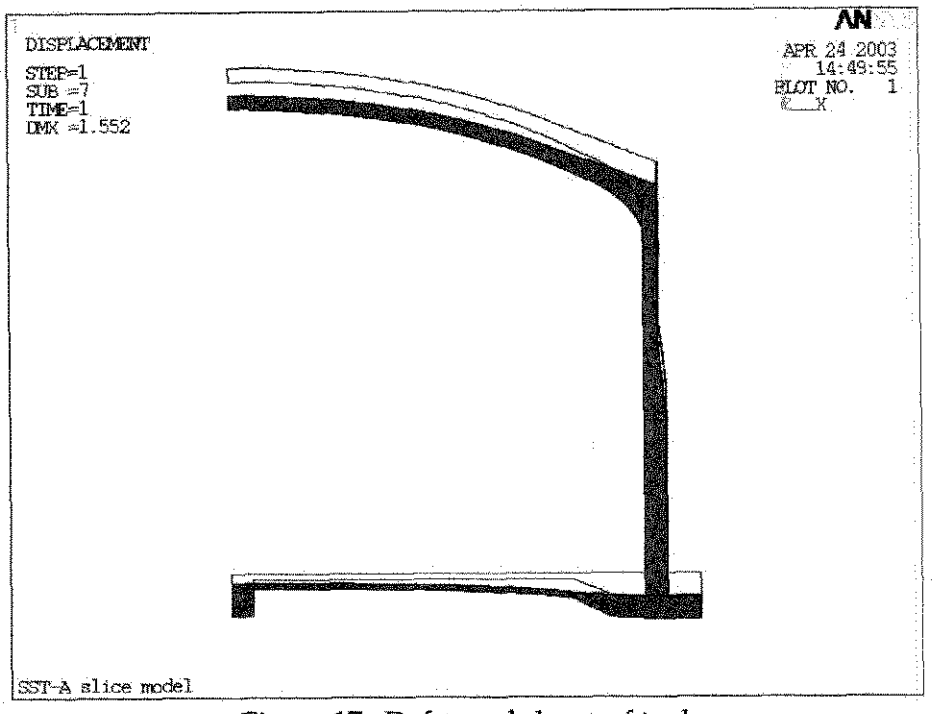

Figure 17. Deformed shape of tank

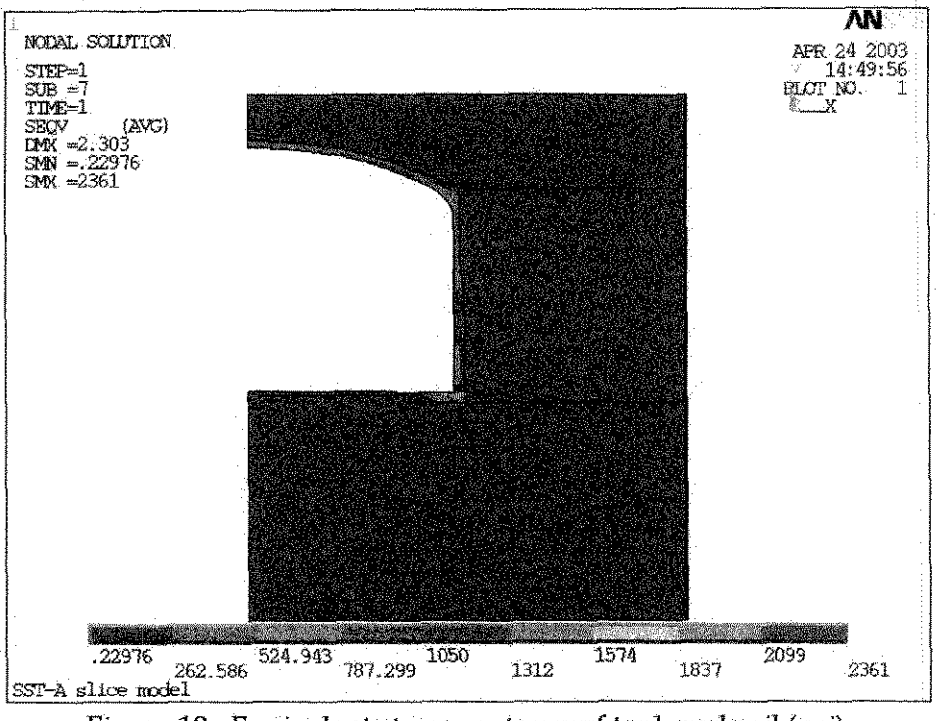

Figure 18. Equivalent stress contours of tank and soil (psi).

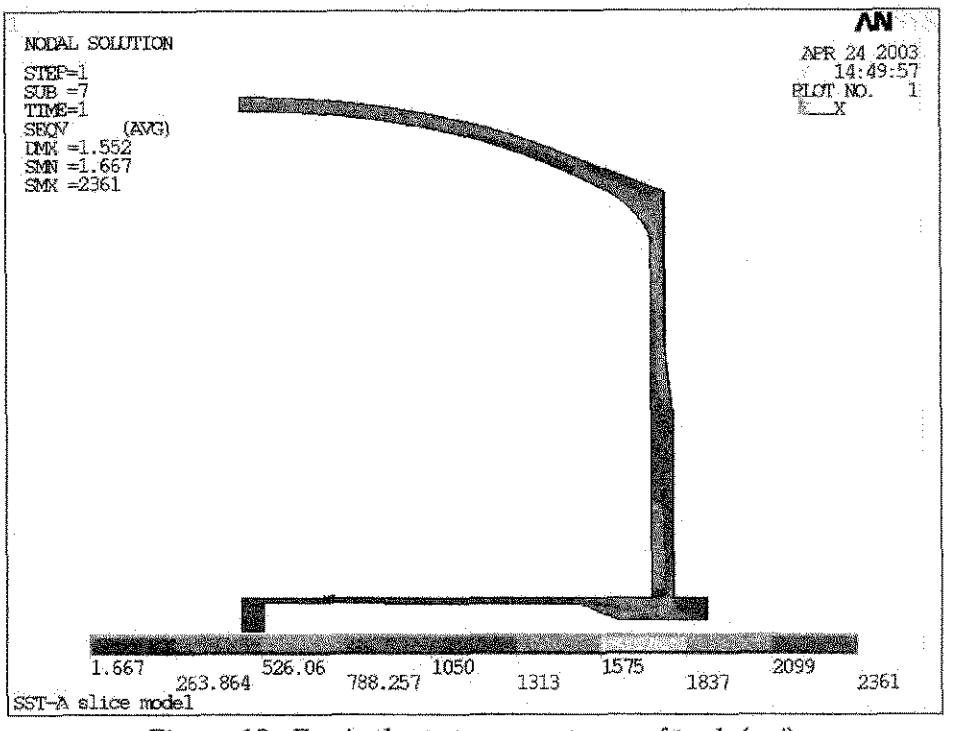

Figure 19. Equivalent stress contours of tank (psi).

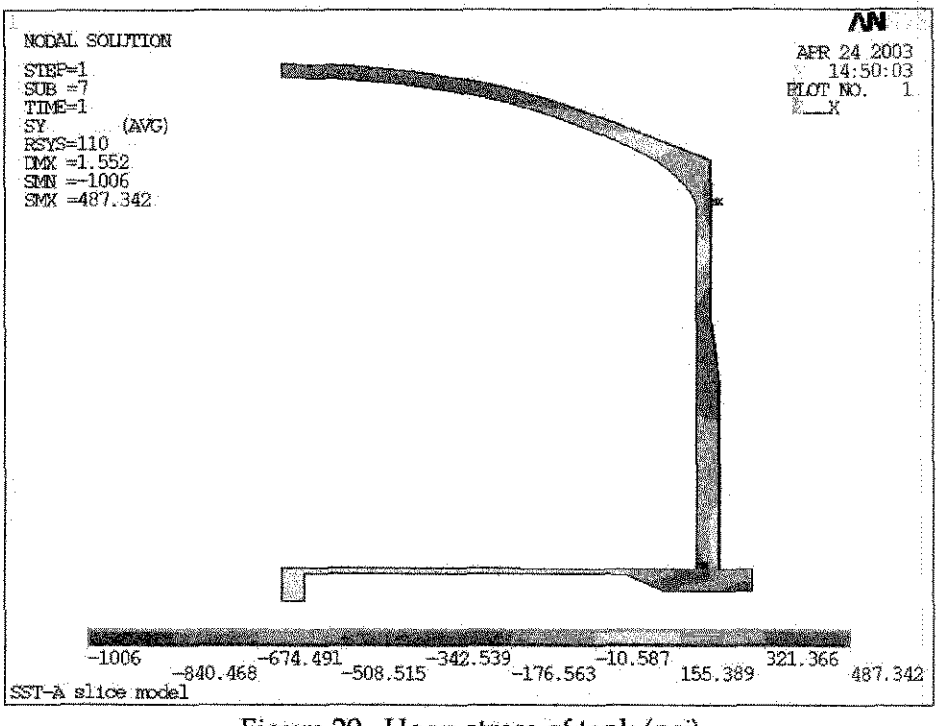

Figure 20. Hoop stress of tank (psi)

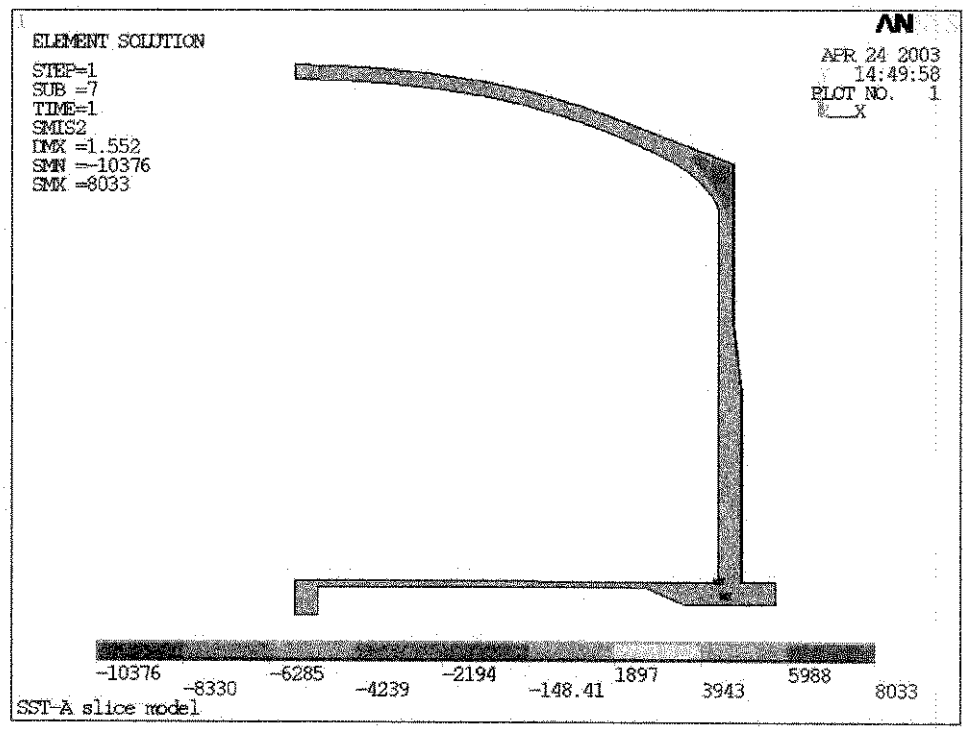

Figure 21. Rebar stresses in first rebar direction

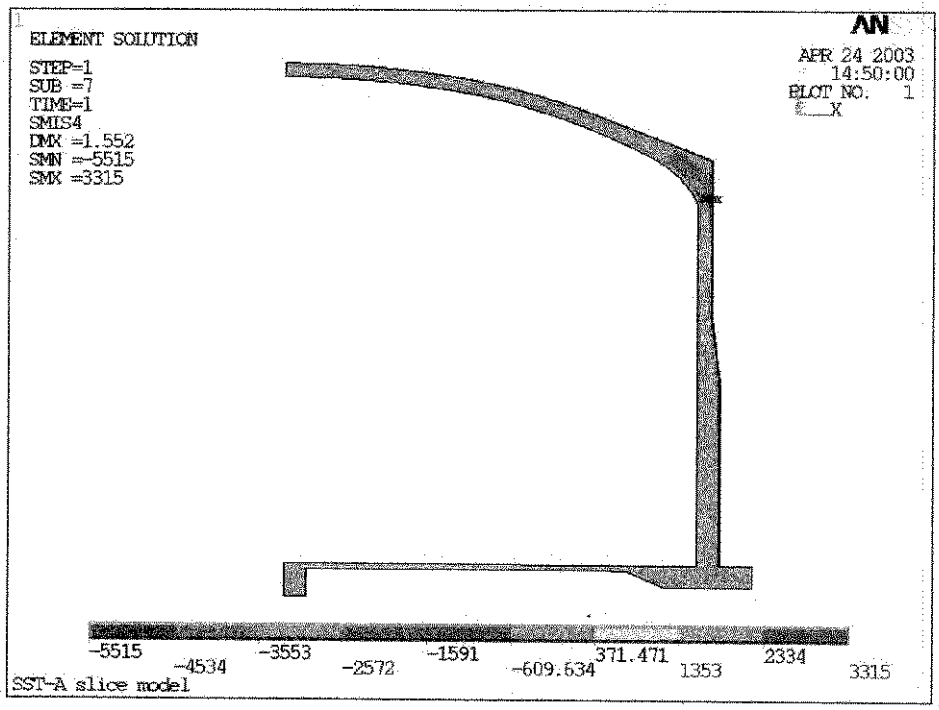

Figure 22. Rebar stresses in second rebar direction

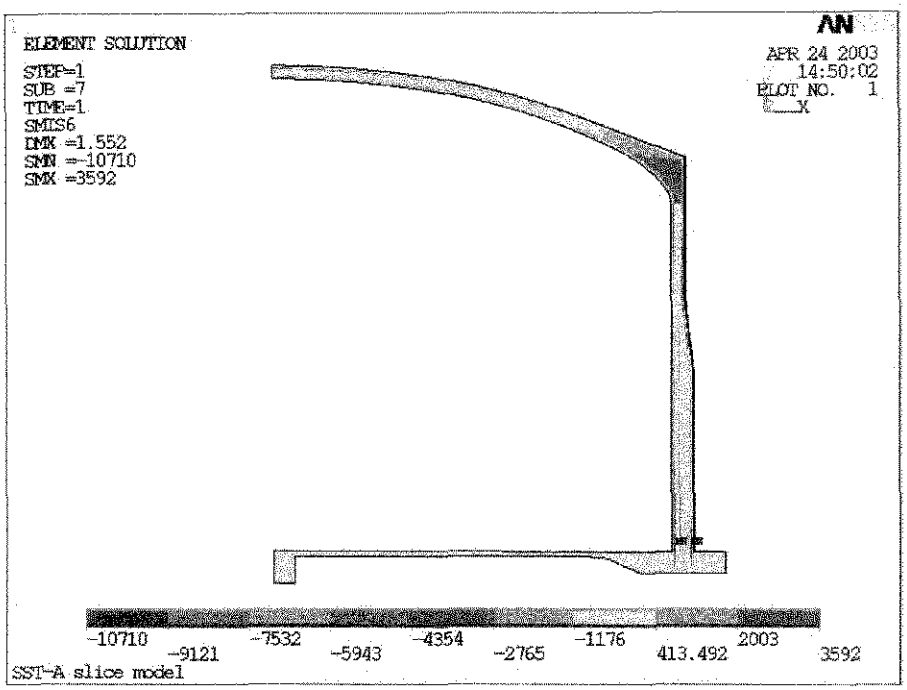

Figure 23. Rebar stresses in third rebar direction

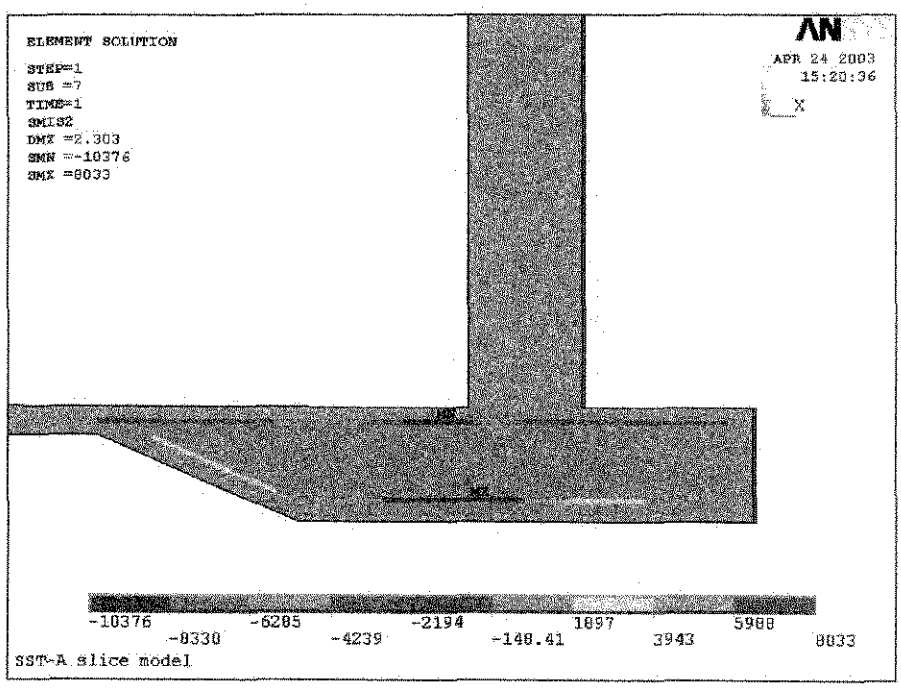

Figure 24. Close up of rebar stresses in first rebar direction

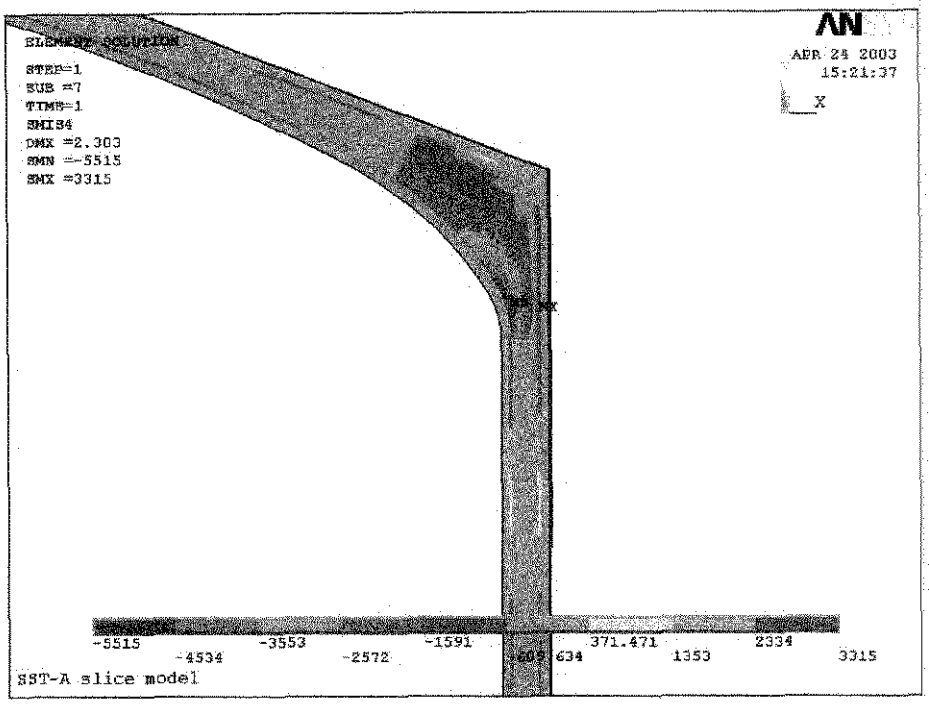

Figure 25. Close up of rebar stresses in second rebar direction

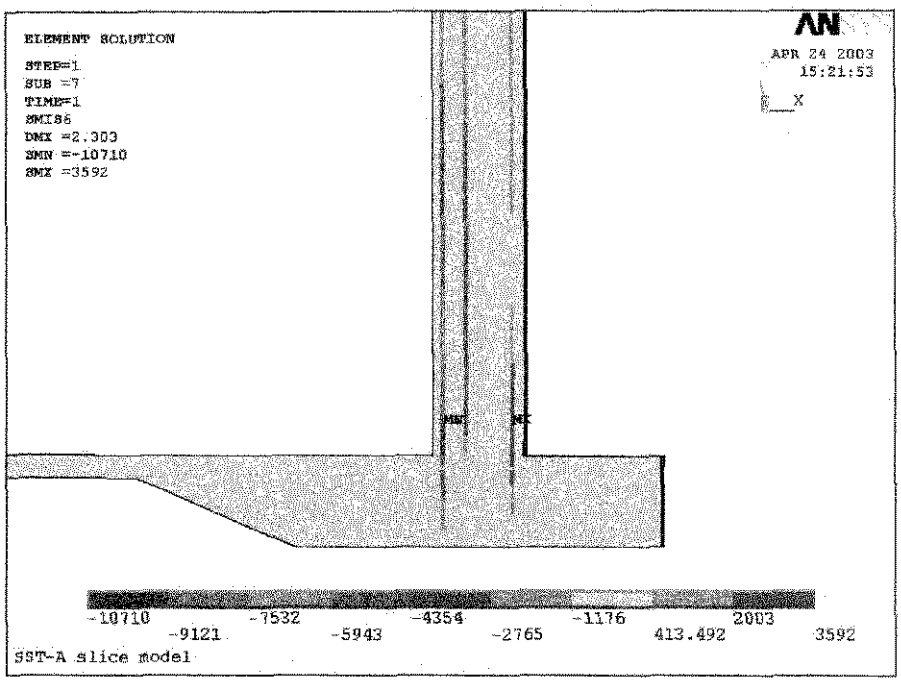

Figure 26. Close up of rebar stress in third rebar direction

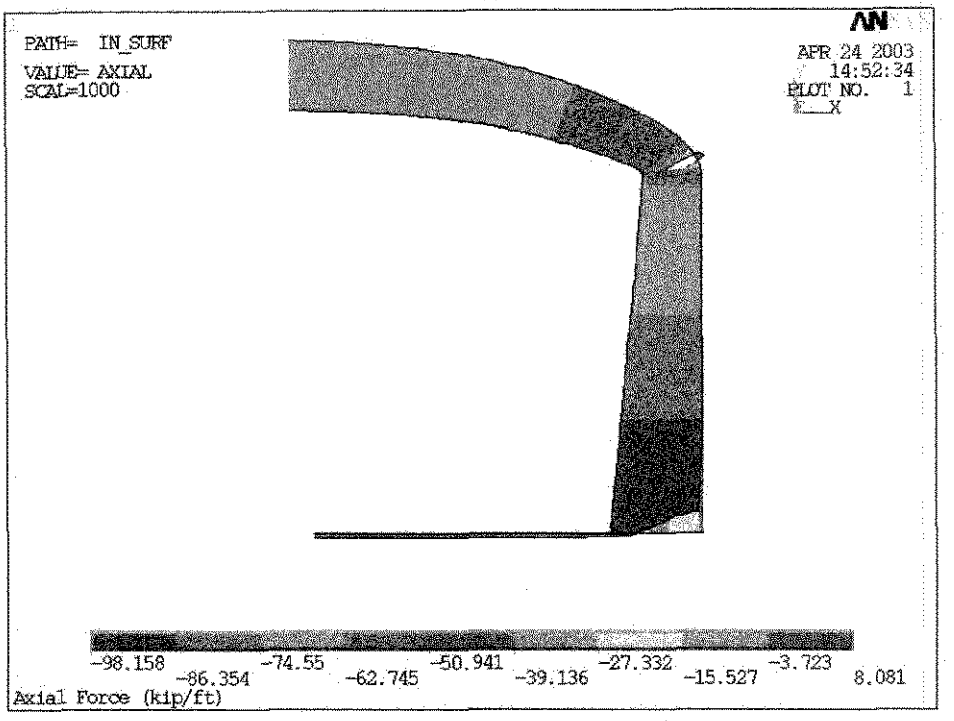

Figure 27. Unit section axial force (kip/ft)

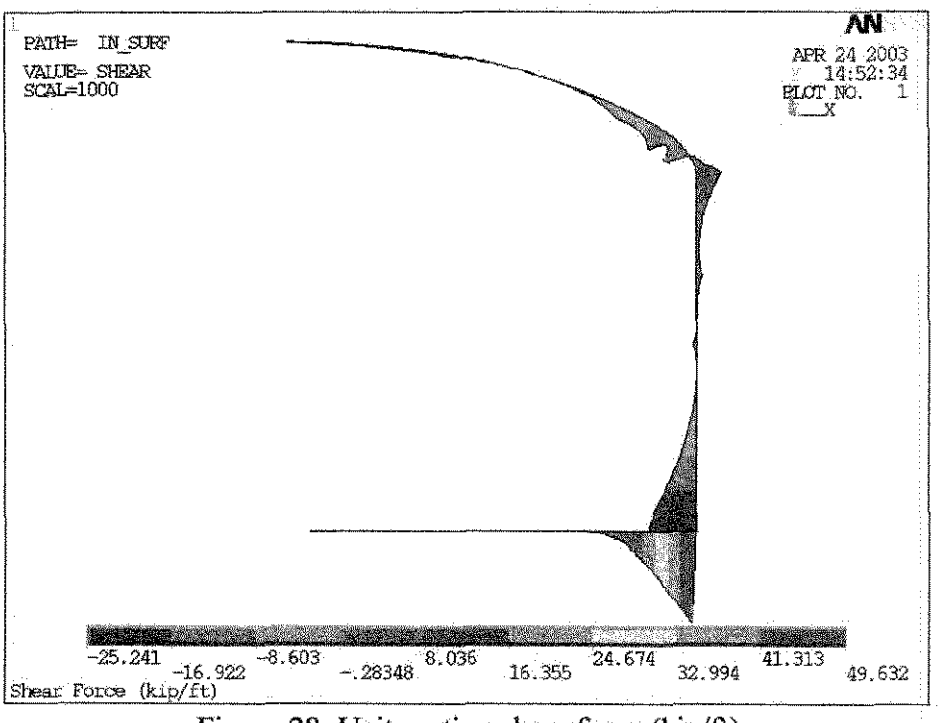

Figure 28. Unit section shear force (kip/ft)

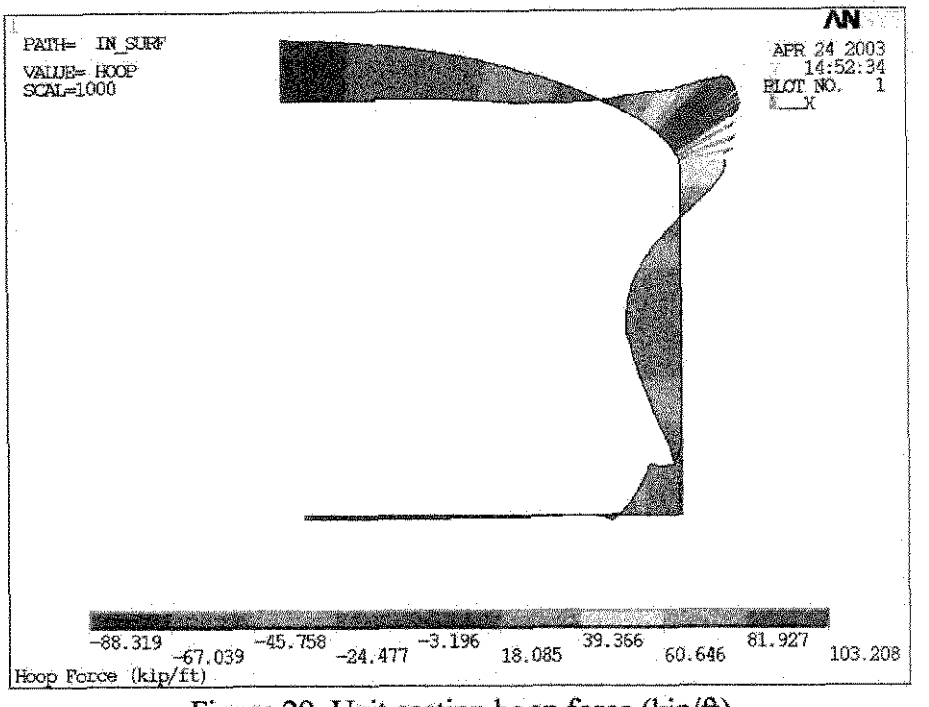

Figure 29. Unit section hoop force (kip/ft)

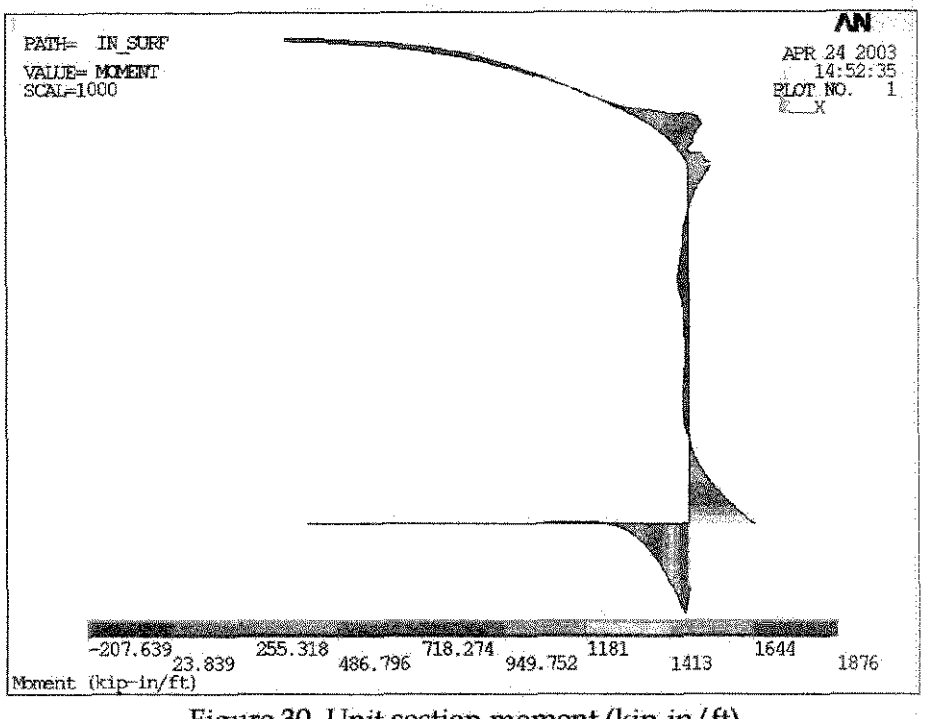

Figure 30. Unit section moment (kip-in/ft)

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-A, 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-2-55911, September 8, 1953

[Ref_5] JLR The Engineering Solutions Company, "Sample AOR Calculation Using ANSYS Axisymmetric Parametric Model for Tank SST-A", RPP-13997, March 11, 2003

7.0 ATTACHMENTS AND APPENDICES

sst_a_slice.mac

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

SHPP,MODIF,1,100,
/INPUT,'parm_a','mac'

!--Create dome
/TRIAD,RTOP
wpcsys,-1,0
wpoff,,dm_r1,
csys,4
k,1
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
k,20,r20,-h20
k,21,r21,-h21

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
lstr,11,12
```

```
lstr,12,13
lstr,13,14
lstr,14,15
lstr,15,16
lstr,16,17
larc,17,18,14,hnch_r2
larc,18,19,14,hnch_r1
larc,19,20,14,dm_r4
larc,20,21,14,dm_r2
lstr,1,21

al,all

!--Cut Tank
lstr,2,20
asbl,1,22
lwpla,-1,19
lsbw,3
lstr,19,22
asbl,3,3
lwpla,-1,16,1
asbw,4
kwpave,7
asbw,5
wprot,,,90
asbw,6
kwpave,16
asbw,7
kwpave,10
asbw,8
kwpave,11
asbw,9
kwpave,12
asbw,10
wprot,,,-90
asbw,11
kwpave,5
asbw,4
kwpave,6
asbw,13

allsel
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,15,,,1
cmsel,u,a_tank
cm,a_soil,area

!--cut soil for different soil properties
kwpave,4
wprot,,90
asbw,all
kwpave,9
lsbw,51
lstr,9,37
asbl,all,51
cm,a_soil,area

wprot,,,90
kwpave,35
wpoff,,,cload_1
lsbw,46

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     Cut Tank for rebar depth
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
rbar_t=1
rbar_dep1=3 !clearance for dome rebar
rbar_dep2=3+7/8-1 !clearance for exterior wall rebar
rbar_dep3=2.125   !clearance for interior wall rebar
rbar_dep4=3.25-.625  !clearance for top slab rebar
rbar_dep5=4 !clearance for bottom slab rebar
rbar_dep6=4 !clearance for side slab rebar

cmsel,s,a_tank
lsla
ksll

lwpla,-1,21
wpoff,,,rbar_dep1
csys,4
k
wpoff,,,rbar_t
k

lwpla,-1,21,1
wpoff,,,-rbar_dep1
k
wpoff,,,-rbar_t
k

lwpla,-1,22
```

```
wpoff,,,rbar_dep1
k
wpoff,,,rbar_t
k

lwpla,-1,22,1
wpoff,,,-rbar_dep1
k
wpoff,,,-rbar_t
k

lwpla,-1,2,1
asbw,1
wpoff,rbar_dep1
k
wpoff,rbar_t
k

lwpla,-1,46,1
wpoff,,,-rbar_dep1
k
wpoff,,,-rbar_t
k

lwpla,-1,3,1
wpoff,,,-rbar_dep1
k
wpoff,,,-rbar_t
k

lwpla,-1,3
wpoff,,,rbar_dep1
k
wpoff,,,rbar_t
k

lwpla,-1,18
wpoff,-(rbar_dep1+rbar_dep3)/2
k
wpoff,-rbar_t
k

lwpla,-1,26
wpoff,,,rbar_dep3
k
wpoff,,,rbar_t
k

lwpla,-1,26,1
wpoff,,,-rbar_dep4
k
```

```
wpoff,,,-rbar_t
k

larc,39,43,15,dm_r1-rbar_depl
larc,40,44,15,dm_r1-rbar_depl-rbar_t
larc,41,45,15,dm_r2+rbar_depl
larc,42,46,15,dm_r2+rbar_depl+rbar_t

larc,43,48,15,dm_r3-rbar_depl
larc,44,49,15,dm_r3-rbar_depl-rbar_t
larc,45,50,15,dm_r4+rbar_depl
larc,46,51,15,dm_r4+rbar_depl+rbar_t

lstr,48,52
lstr,49,53
larc,51,55,15,dm_r4+rbar_depl+rbar_t
larc,50,54,15,dm_r4+rbar_depl

larc,55,57,15,hnch_r1+rbar_depl+rbar_t
larc,54,56,15,hnch_r1+rbar_depl
larc,57,59,15,hnch_r2+rbar_depl+rbar_t
larc,56,58,15,hnch_r2+rbar_depl
asbl,all,all

lwpla,-1,64,1
wprot,,,90
asbw,36
kwpave,53
asbw,3

lwpla,-1,93
kwpave,60
asbw,2
asbw,11
asbw,15
kwpave,61
asbw,18
asbw,36
asbw,37

!--cut wall for rebar depth
kwpave,60
asbw,33
kwpave,61
asbw,41
kwpave,59
asbw,42
kwpave,58
asbw,43
asbw,4
asbw,6
```

```
asbw,14
kwpave,59
asbw,43
asbw,46
asbw,47

lwpla,-1,5
wprot,,,90
kwpave,72
asbw,50
kwpave,73
asbw,51

lwpla,-1,132,1
asbw,14
asbw,49
kwpave,82
asbw,14
asbw,53

!cut slab for rebar depth
lwpla,-1,7,1
wpoff,,,-rbar_dep6
asbw,5
wpoff,,,-rbar_t
asbw,57

lwpla,-1,8
wpoff,,,rbar_dep4
asbw,all
wpoff,,,rbar_t
asbw,all

lwpla,-1,192
wpoff,,,rbar_dep5
asbw,4
asbw,8
asbw,9
asbw,43
asbw,49
asbw,53
asbw,54
asbw,55
asbw,58
wpoff,,,rbar_t
asbw,60
asbw,61
asbw,62
asbw,63
asbw,66
asbw,69
```

```
asbw,75
asbw,76
asbw,78

lwpla,-1,10
wprot,,,90
kwpave,132
asbw,5
kwpave,122
asbw,101

wpcsys,-1,0
kwpave,138
wprot,,,90
asbw,5
asbw,65
asbw,84
asbw,102

kwpave,139
asbw,104
asbw,105
asbw,106

cm,a_tank,area

!--cut wall for center rebar
wl_h1=248
wl_h2=248-58
wl_h3=13*12
wl_h4=21*12+4.5
wl_h5=wl_h4+42

lwpla,-1,6,1
wpoff,,,-wl_h1
asbw,6
asbw,46
asbw,47
asbw,50
asbw,52

lwpla,-1,122
wpoff,,,6
asbw,43
asbw,51
asbw,63
asbw,73
asbw,90
asbw,96
asbw,114
```

```
wpoff,,,-rbar_t
asbw,43
asbw,51
asbw,52
asbw,63
asbw,73
asbw,90
asbw,96

lwpla,-1,6,1
wpoff,,,-wl_h2
asbw,14
asbw,45
asbw,48
asbw,56
asbw,114
asbw,116
asbw,122

lwpla,-1,276
wpoff,,,wl_h3
asbw,14
asbw,45
asbw,56
asbw,96
asbw,116
asbw,132
asbw,134

kwpave,7
wpoff,,,wl_h4
asbw,6
asbw,46
asbw,47
asbw,50
asbw,106

kwpave,7
wpoff,,,wl_h5
asbw,33
asbw,37
asbw,41
asbw,42
asbw,44

!--cut dome for rebar length
dm_rbar_r1=75

dm_rbar_r2=120
dm_rbar_r3=240
dm_rbar_r4=31*12+6
```

```
dm_rbar_r5=35*12+6

wpcsys,-1,0
wprot,,,90

kwpave,1
wpoff,,,dm_rbar_r1
lsbw,1

kwpave,1
wpoff,,,dm_rbar_r2
lsbw,346

kwpave,1
wpoff,,,dm_rbar_r3
lsbw,2

kwpave,1
wpoff,,,dm_rbar_r4
lsbw,23

kwpave,1
wpoff,,,dm_rbar_r5
lsbw,93

lwpla,-1,115,1
asbw,1
asbw,20
asbw,21
asbw,25
asbw,26

lwpla,-1,347,1
asbw,20
asbw,153
asbw,154
asbw,156
asbw,157

lwpla,-1,346,1
asbw,19
asbw,23
asbw,27
asbw,28
asbw,29

lwpla,-1,2,1
asbw,22
asbw,24
asbw,30
asbw,31
```

```
asbw,32

lwpla,-1,90
kwpave,201
wprot,,,90
asbw,15
asbw,34
asbw,35
asbw,39
asbw,40
cm,a_tank,area

lstr,4,65
lstr,65,70
asbl,3,400
asbl,18,401
lwpla,-1,401
wprot,,,90
asbw,174
asbw,175
asbw,177

aadd,38,178
aadd,173,177
aadd,176,179
aadd,2,40
aadd,176,11
aadd,3,36

lsel,s,,,22
lsel,a,,,104
lsel,a,,,350
lcomb,all

lsel,s,,,3
lsel,a,,,26
lsel,a,,,46
lcomb,all

lsla
lcomb,392,105
lcomb,24,100

lwpla,-1,30,1
wpoff,,,-1
asbw,5
asbw,65
asbw,78
asbw,84
asbw,103
```

```
aadd,101,109
aadd,65,84
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
```

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Subject	**Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-A**		
Originator	Xianghong Li	Date	4/24/03
Checker	Jim Radochia	Date	4/24/03

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

!-- slab rebar
asel,s,,,85
asel,a,,,87
aatt,mat_conc,100,type_2d_rebar

asel,s,,,63
asel,a,,,5
asel,a,,,40
asel,a,,,82,83
asel,a,,,86,89,3
asel,a,,,104
asel,a,,,108
asel,a,,,119
asel,a,,,88,92,4
asel,a,,,43
asel,a,,,61,62
asel,a,,,79,81,2
asel,a,,,97
asel,a,,,100
asel,a,,,117
asel,a,,,123
asel,a,,,69
asel,a,,,126
asel,a,,,93
aatt,mat_conc,101,type_2d_rebar

asel,s,,,178
aatt,mat_conc,102,type_2d_rebar

asel,s,,,76
aatt,mat_conc,103,type_2d_rebar

asel,s,,,95,98,3
asel,a,,,71
asel,a,,,77
aatt,mat_conc,104,type_2d_rebar

!--- Wall rebar (layer 1 interior)
asel,s,,,137
aatt,mat_conc,204,type_2d_rebar

asel,s,,,14
```

```
asel,a,,,111
asel,a,,,131
asel,a,,,134
aatt,mat_conc,203,type_2d_rebar

asel,s,,,143
asel,a,,,152
aatt,mat_conc,202,type_2d_rebar

asel,s,,,42
aatt,mat_conc,201,type_2d_rebar

!Wall rebar layer 2
asel,s,,,96
asel,a,,,140
aatt,mat_conc,206,type_2d_rebar

asel,s,,,135
asel,a,,,128
aatt,mat_conc,205,type_2d_rebar

!wall rebar layer 3
asel,s,,,116
aatt,mat_conc,204,type_2d_rebar

asel,s,,,141
asel,a,,,48
aatt,mat_conc,203,type_2d_rebar

asel,s,,,113
asel,a,,,145
aatt,mat_conc,207,type_2d_rebar

asel,s,,,46
aatt,mat_conc,208,type_2d_rebar

asel,s,,,148
aatt,mat_conc,202,type_2d_rebar

asel,s,,,106
aatt,mat_conc,201,type_2d_rebar

!---External dome rebar
asel,s,,,1
aatt,mat_conc,300,type_2d_rebar

asel,s,,,160
aatt,mat_conc,301,type_2d_rebar

asel,s,,,153
aatt,mat_conc,302,type_2d_rebar
```

```
asel,s,,,23
aatt,mat_conc,303,type_2d_rebar

asel,s,,,165
aatt,mat_conc,304,type_2d_rebar

asel,s,,,24
aatt,mat_conc,305,type_2d_rebar

asel,s,,,35
asel,a,,,170
aatt,mat_conc,306,type_2d_rebar

asel,s,,,173
aatt,mat_conc,307,type_2d_rebar

asel,s,,,11
aatt,mat_conc,308,type_2d_rebar

!---Interna dome rebar
asel,s,,,25
aatt,mat_conc,300,type_2d_rebar

asel,s,,,156
aatt,mat_conc,301,type_2d_rebar

asel,s,,,162
aatt,mat_conc,302,type_2d_rebar

asel,s,,,28
aatt,mat_conc,303,type_2d_rebar

asel,s,,,167
aatt,mat_conc,304,type_2d_rebar

asel,s,,,31
aatt,mat_conc,305,type_2d_rebar

asel,s,,,34
asel,a,,,172
aatt,mat_conc,306,type_2d_rebar

asel,s,,,174
asel,a,,,181
aatt,mat_conc,309,type_2d_rebar

!----Haunch interior region
asel,s,,,39
asel,a,,,171
aatt,mat_conc,501,type_2d_rebar
```

```
asel,s,,,175
asel,a,,,182
aatt,mat_conc,502,type_2d_rebar

allsel

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


!-- tank mesh
cmsel,s,a_tank
allsel,below,area

esize,tank_size
type,type_2d_conc
mat,mat_tank

lccat,17,405
lccat,406,71
lccat,407,70
lccat,236,245
lccat,100,154

lsel,s,,,278
lsel,a,,,291,293,2
lccat,all
lsla

lesize,72,,,2
lesize,78,,,2
lesize,175,,,2
lesize,211,,,2

mshkey,1
asel,u,,,65
amesh,all

!--delete concat 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

!-- 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,49,,,8,5
lesize,50,,,10,5

lesize,54,,,8
lesize,47,,,25,4
lesize,51,,,25,4

mshkey,0
amesh,all

wpcsys,-1,0
kwpave,1
csys,4
cmsel,s,a_soil
asel,r,loc,y,-h4,999999
esla
emodif,all,mat,mat_tsoil
cm,t_soil,area

cmsel,s,a_soil
asel,r,loc,y,-h4,-h9
esla
emodif,all,mat,mat_msoil
cm,m_soil,area

cmsel,s,a_soil
asel,r,loc,y,-h9,-99999
esla
emodif,all,mat,mat_bsoil
cm,b_soil,area

![[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[[
!
```

```
!     3D mesh by rotation, reassign general elem. attr.
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
allsel
type,type_3d_soil
extopt,attr,1,1,1
extopt,esize,1
vrotat,all,,,,,,1,15,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=452
b=157
wpcsys,-1,0
kwpave,41
wpoff,,-b
cswpla,100,2,b/a

!--- csys 101 sperical: external dome/haunch
a=600
b=300
wpcsys,-1,0
kwpave,40
wpoff,,-b
cswpla,101,2,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,,,25
asel,a,,,28
asel,a,,,31
asel,a,,,34
asel,a,,,39
asel,a,,,156
asel,a,,,162
asel,a,,,167
asel,a,,,171,172
asel,a,,,174,175
asel,a,,,181,182
vsla
eslv
emodif,all,esys,100

asel,s,,,1
asel,a,,,23,24
asel,a,,,35
asel,a,,,153
```

```
asel,a,,,160
asel,a,,,165
asel,a,,,170
asel,a,,,173
vsla
eslv
emodif,all,esys,101


esel,s,type,,type_3d_rebar
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)=.0256,.0785,.0785,.0000,.0000
vry(1)=.0256,.0256,.0256,.0000,.0000
vrz(1)=.0000,.0000,.0000,.0000,.0785
rc(1)=100,101,102,103,104
*do,i,1,5
      r,rc(i),mat_srebar,vrx(i),0,0,mat_srebar,vry(i)
      rmore,90,0,mat_srebar,vrz(i),90,90
*enddo

!redefine real 102 for angle
r,102,mat_srebar,vrx(3),0,-23.2,mat_srebar,vry(3),
rmore,90,0,mat_srebar,vrz(3),90,90

!wall
vrx=
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
```

```
*dim,rc,,20
vrz(1)=.0393,.0393,.0393,.0785,.0128,.0128,.0393,.0393
vry(1)=.0982,.1309,.1653,.1653,.1653,.0982,.1653,.1309
rc(1)=201,202,203,204,205,206,207,208
*do,i,1,8
      r,rc(i),mat_null,0,0,0,mat_rebar,vry(i)
      rmore,90,0,mat_rebar,vrz(i),90,90
*enddo

!redefine real constant for inclined wall rebar (r207)
r,rc(7),mat_null,0,0,0,mat_rebar,vry(7)
rmore,90,0,mat_rebar,vrz(7),0,97.125

r,rc(8),mat_null,0,0,0,mat_rebar,vry(8)
rmore,90,0,mat_rebar,vrz(8),0,97.125

!dome and haunch
vrx=
vrz=
vry=
rc=
*dim,vrx,,20
*dim,vry,,20
*dim,vrz,,20
*dim,rc,,20
vry(1)=.0736,.0437,.0564,.0403,.0582,.0471,.0848,.0767,.2560,.0767
vrz(1)=.0736,.0368,.0368,.0368,.0368,.0833,.1193,.1403,.0736,.0934
rc(1)=300,301,302,303,304,305,306,307,308
*do,i,1,10
      r,rc(i),mat_null,0,0,0,mat_rebar,vry(i)
      rmore,90,0,mat_rebar,vrz(i),90,90
*enddo

!haunch core

r,501,mat_rebar,.0,0,0,mat_rebar,0.0000
rmore,30,0,mat_rebar,.0165,90,90

r,502,mat_rebar,.0014,0,0,mat_rebar,0.0019
rmore,55,0,mat_rebar,.0274,90,90

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,500,510
    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,,,183
asel,a,,,194
asel,a,,,202
asel,a,,,207
asel,a,,,212
asel,a,,,217

asel,a,,,222,223
asel,a,,,235,243
asel,a,,,257,271
asel,a,,,276,287
cm,tk_cnt_area,area
lsla
nsla,,1
```

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Subject	**Sample AOR Calculation using ANSYS Slice Parametric Model for Tank SST-A**		
Originator	Xianghong Li	Date	4/24/03
Checker	Jim Radochia	Date	4/24/03

```
esln
type,22
real,21
mat,21
esurf

asel,s,,,753,761
asel,a,,,766,775
asel,a,,,777,782
asel,a,,,788,805
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

!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
!
!     set up AOR loadings and solve
!
!]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]

slice_load_a
allsel
finish
/filname,sst_a_slice
/title,SST-A slice model
/solu
nlgeom,on
nsubst,10,100,5
save
solve
```

parm_a.mac

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

t1=15  !tank wall thichness at bottom
t2=24      !tank wall thickness at top

dm_r1=1155  !inch, radius of outer inboard dome surface
dm_r2=1140  !inch, radius of inner inboard dome surface
dm_r3=804   !inch, radius of outer outboard dome surface
dm_r4=720   !inch, radius of inner outboard dome surface

hnch_r1=120 !inch, big haunch radius
hnch_r2=2*12+2+1/2      !inch, small haunch radius

depth=8.45*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=12+2+1/2

r3=r2+13*12+7+1/16
h3=4*12+10.5

r4=38*12+9+1/2
h4=8*12+8+15/16

r5=r4
h5=h4+(4*12+6+1/16)+(9*12+6+3/4)

r6=r5+(t2-t1)
h6=h5+6*12

r7=r6
h7=h6+17*12

r8=r7+3*12
h8=h7

r9=r8
h9=h8+2*12

r10=r9-8*12
```

```
h10=h9

r11=r10-(3*12+6)
h11=h7+6

r12=24
h12=h11

r13=r12
h13=h12+(2*12+6)

r14=0
h14=h13

r15=0
h15=h7

r16=r7-t2
h16=h7

r21=0
h21=dm_r1-dm_r2

r20=r21+15*12
h20=h21+12+2+5/16

r19=r20+(18*12+4+5/8)
h19=h20+(6*12+1+5/16)

r18=r19+(3*12+9+13/16)
h18=h19+(3*12+6+1/4)

r17=r18+4+1/16
h17=h18+(12+2+1/8)

!---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=40
cload_div=11
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_a.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

asel,s,,,751,752
lsla
nsla,,1
esln
sf,all,pres,p_uniform

p_cload=ff/(3.14159*cload_l**2)
asel,s,,,752
lsla
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_a_slice.mac

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

/post1
set,last

!-----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
nsle
/rep
plpng

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

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

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

plesol,smisc,4
plpng

plesol,smisc,6
plpng

rsys,110
plnsol,s,y
plpng

!--------------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,,,22,23
lsel,a,,,115
lsel,a,,,346,349
nsll,,1
cm,nd_out,node

lsel,s,,,60
lsel,a,,,64
lsel,a,,,102
lsel,a,,,357
lsel,a,,,360
```

```
lsel,a,,,363
lsel,a,,,375
lsel,a,,,385
lsel,a,,,402
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,4,227
```

```
csys,4
asel,r,loc,x,0,-99999
asel,r,loc,y,-1,99999
asel,a,,,18
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

!===============upper thinner wall
lsel,s,,,3
lsel,a,,,14
lsel,a,,,31
lsel,a,,,133
lsel,a,,,260
lsel,a,,,296
lsel,a,,,318
lsel,a,,,329
lsel,a,,,339
nsll,,1
cm,nd_out,node

lsel,s,,,17
lsel,a,,,110
lsel,a,,,255
lsel,a,,,299
lsel,a,,,308
lsel,a,,,311
lsel,a,,,332
lsel,a,,,334
lsel,a,,,344
lsel,a,,,405
nsll,,1
cm,nd_in,node

cmsel,s,a_tank
wpcsys,-1,0
kwpave,16
cmsel,u,dome_area
csys,4
asel,r,loc,y,0,9999
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,,,11
lsel,a,,,32
lsel,a,,,215
lsel,a,,,244
lsel,a,,,252
lsel,a,,,350
nsll,,1
cm,nd_out,node

lsel,s,,,10
lsel,a,,,21
lsel,a,,,33
lsel,a,,,37
lsel,a,,,95
lsel,a,,,249
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_a,plt
axial_path
plpng

shear_path
plpng

hoop_path
plpng

moment_path
plpng
```

```
!----Output path data to file
/sys,del path_a.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_a,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_a.plt

```
/NOPR
/RESET
/DEVICE,VECT,OFF
! General Graphics Settings
/NUM,  1
/PLOP,INFO, 3
/TRIAD,RTOP
/GTHIC,CURV,  2
/GROPT,CURL,  1
/PNUM,TYPE, 1
/COL, NUM ,YGRE, 3
/TRLCY,ON
/TXTRE,ON
/COL, PBAK,0, 1,  4
! Window Settings
/VIEW,1,  0.0000    ,  0.0000    ,  1.0000
/FOC, 1,  199.98    ,  793.52    , 0.50000
/DIST,1,  379.29
/TYPE,1, 6
/EDG, 1, 0,  45.000
/CONT,1,  9,AUTO
/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,TYPE, 1
/COL, NUM ,YGRE, 3
/TRLCY,ON
/TXTRE,ON
/COL, PBAK,0, 1,  4
! Window Settings
/VIEW,1,  0.0000    ,  0.0000    ,  1.0000
/FOC, 1,  202.25    ,  832.21    , 0.50000
/DIST,1,  379.29
/TYPE,1, 6
/EDG, 1, 0,  45.000
/CONT,1,  9,AUTO
/GO
```