# **Analysis of Underground** Water Tank



ACECOMS, AIT



# Analysis of Underground Water Tank

# **Using SAP2000**

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# Objective

To demonstrate and practice step-by-step on the modeling and static analysis of underground water tank

# Problem

Carry out static analysis of underground water tank with the following details





3D View

**Section View** 

## Material Properties (Use Default Material)

Compressive strength of concrete (f'c)	=	281	kg/cm <sup>2</sup>
Young Modulus of concrete (E <sub>c</sub> )	= 2	53,105	kg/cm <sup>2</sup>
Unit Weight of Concrete	=	2,403	kg/m <sup>3</sup>
Unit Weight of Water	=	1,000	kg/m³
Unit Weight of Soil	=	1,800	kg/m <sup>3</sup>
Coefficient of Active Earth Pressure (Ka)	=	0.6	
(Assuming the back fill is cohesive)			

## Modulus of Subgrade Reaction (K<sub>S</sub>) Properties

Direction	Value (T/m²/m)
Vertical (z)	1200
Horizontal (x and y)	500

### **Shell Section Properties**

Location	Section
Top Slabs	15 cm
Bottom Slabs	30 cm
Walls	25 cm

#### Load Cases and Details

Load Name	Load Type	Details
DEAD	Dead Load	Self Weight: Calculate automatically using Self Weight Multiplier in SAP2000
LIVE	Live Load	250 kg/m <sup>2</sup> on Top Slabs
TANK1	Weight & Pressure of Fluid	Weight and Pressure of Water on Walls and Bottom Slabs in Tank 1
TANK2	Weight & Pressure of Fluid	Weight and Pressure of Water on Walls and Bottom Slabs in Tank 2
TANK3	Weight & Pressure of Fluid	Weight and Pressure of Water on Walls and Bottom Slabs in Tank 3
SOIL	Weight & Pressure of Soil	Soil Pressure on All Side Walls and Cantilever Part of Base Slab (Not including any surcharge from service vehicles)
UPLIFT	Pressure of Water	Uplift Pressure on Bottom Slabs (3.5 T/m <sup>2</sup> : Upward)

Load Combinations (without Sanitary Durability Coefficient)

Load Comb. No.	Details
1	U = 1.4 DEAD + 1.7 WATER
2	U = 1.2 DEAD + 1.7 WATER + 1.6 LIVE +1.7 SOIL
3	U = 1.2 DEAD + 1.7 WATER + 1.6 LIVE +1.7 SOIL + 1.7 UPLIFT
4	U = 1.2 DEAD + 1.0 LIVE
5	U = 0.9 DEAD + 1.7 SOIL + 1.7 UPLIFT

Sanitary Durability Coefficient (Modified ACI Capacity Factors for Water Retaining Structure)

Reinforcement in Flexure	= 1.3 U
Direct Tension/Hoop Reinforcement	= 1.6 U
Excess Shear (for Stirrup)	= 1.3 U
Compression + Flexure	= 1.0 U

# Step by Step

# 1. Start Model with Template

#### Step 1-1: Select Working Unit and Start New Model with Template Start up screen of SAP2000, select working unit to be "ton-m" at drop-down menu on the bottom-right of screen and click on D to start new model with template



## Step 1-2: Select Template

Select "Grid Only" by clicking on it



Step 1-3: Specify Grid System Specify grid system as shown in above figure and click "OK".

New Coord/Grid System		
Cartesian	Cylindrical	
System Name	GLOBAL	
- Number of Grid Lin	ies	
× direction	4	
Y direction	4	
Z direction	5	
Grid Spacing		
× direction	6.	
Y direction	6.	
Z direction	3.	
Edit Grid Cancel		

# 2. Define Material Properties

#### Step 2-1: Change Working Unit

Change working unit to "kg-cm"



#### Step 2-2: Modify Material Properties

Go to Define >> Materials..., and select "CONC", click on "Modify/ Show Material..."

Define Materials			
Materials	Click to: Add New Material Modify/Show Material Delete Material OK Cancel		

#### Step 2-3: Accept the Default Values

Click "OK" to accept the default values. Next, also click "OK" in the preceding window (Define Materials).

Material Property Data			
Material Name CONC	Display Color Color		
Type of Material C Isotropic C Anisotropic C Uniaxial	Type of Design Design Concrete		
Analysis Property DataMass per unit Volume2.450E-06Weight per unit Volume2.403E-03Modulus of Elasticity253105.07Poisson's Ratio0.2Coeff of Thermal Expansion9.900E-06Shear Modulus105460.45	Design Property Data (ACI 318-05/IBC 2003)         Specified Conc Comp Strength, I'c       281.2279         Bending Reinf. Yield Stress, fy       4218.4178         Shear Reinf. Yield Stress, fys       2812.2785         Lightweight Concrete       Shear Strength Reduc. Factor         Shear Strength Reduc. Factor       1.0		
Advanced Material Property Data Time Dependent Properties Material Damping Properties Stress-Strain Curve Definitions	OK Cancel		

## 3. Define Shell Sections

Three shell sections (thick. = 15, 25 and 30 cm) are required in this model.

#### Step 3-1: Add New Shell Section

Go to **Define >> Area Section**, select "Shell" from drop-down menu and click on "Add New Section".



#### Step 3-2: Specify Shell Section Properties

Specify shell section properties as shown below for shell section thickness = 15 cm. Afterwards, click "OK".

hell Section Data	
Section Name	TH15CM Display Color
Туре	
Shell - Thin	
C Shell - Thick	
🔿 Plate - Thin	
C Plate - Thick	
Membrane	
C Shell - Layered/No	nlinear
Modify/	Show Layer Definition
Material	
Material Name	CONC
Material Angle	0.
Thickness	
Membrane	15
Bending	15
-	
Concrete Shell Section I	Jesign Parameters
Modify/Show S	hell Design Parameters
Stiffness Modifiers	Temp Dependent Properties-
Set Modifiers	Thermal Properties
ОК	Cancel
	·

#### Step 3-3: Add 2 New Shell Sections

Repeat Step 3-1 and 3-2 to add two more shell sections with thicknesses of 25 and 30 cm, respectively. Next, click "OK".

Area Sections			
Sections ASEC1 TH15CM TH25CM TH30CM	Select Section Type To Add Shell Click to: Add New Section Add Copy of Section Delete Section OK Cancel		

# 4. Modify Grid System

#### Step 4-1: Modify Grid System

Select working unit to be "Ton, m, C", go to **Define >> Coordinate System/Grid** and click on "Modify/Show System..."



#### Step 4-2: Modify Grid System

Modify grid system as shown below. Click "OK" button. Next, also click "OK" in the preceding window (Coordinate/ Grid Systems).

🐹 D	efine (	Grid Data						X
Edit Eormat								
								Units
			Sustem Nam	<b>P</b>	GLOBAI		_	
					1			
<sub>E</sub> >	< Grid Da	ita				_		
		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	Grid Color	
	1	x1	-0.5	Primary	Show	End		
	2	×2	0.	Primary	Show	End		
	3	x3	5.	Primary	Show	End		
	4	<b>×</b> 4	10.	Primary	Show	End		
	5	x5	15.	Primary	Show	End		
	6	x6	15.5	Primary	Show	End		
	<u> </u>							
	8					ļ]		
ר∟	' Grid Da	ita 🗾 💻	-		_			Display Grids as
		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	Grid Color 🔺	🖲 Ordinates 🔿 Spacing
	1	y1	-0.5	Primary	Show	End		
	2	<b>y</b> 2	0.	Primary	Show	End		
	3	у3	4.	Primary	Show	End		Hide All Grid Lines
	4	• y4	4.5	Primary	Show	End		🔲 Glue to Grid Lines
	5	L					· · · · · · · · · · · · · · · · · · ·	
	- 5							Bubble Size 2.4384
		h =						
6	and Da				-			Reset to Default Color
		Grid ID	Ordinate	Line Type	Visibility	Bubble Loc.	-	
	1	z1	0.	Primary	Show	End		Reorder Ordinates
	2	• z2	3.	Primary	Show	End		
	3	z3	3.5	Primary	Show	End		
	4							
	6							c = - a
	7							
	8							UK Cancel

# 5. Draw Top Slabs

#### Step 5-1: Change Plan View to Top Slab Level

Select left window, click on  $\sim$  Set XY View button to change view to plan view and and click on  $\sim$  or  $\sim$  to move to move plan level to Z = 3.5 m. Plan elevation (X-Y Plane) is displayed at top-left of window.



Step 5-2: Fill Object to Show Shell Element

Go to View >> Set Display Options, select "Fill Object" and "Apply to All Windows". Next, click "OK".

Joints	Frames/Cables/Tendons	General	View by Colors of
🗐 Labels	🔽 Labels	F Shrink Objects	Objects
✓ Restraints	Sections	Extrude View	C Sections
✓ Springs	F Releases	🔽 Fill Objects	C Materials
Local Axes	🗖 Local Axes	🕂 🔽 Ohow Edges 🛁	C Color Printer
🔽 Invisible	Frames Not in View	🔽 Show Ref. Lines	C White Background, Black Objects
Not in View	Cables Not in View	📕 Show Bounding Boxes	C Selected Groups Select Groups
	🔲 Tendons Not in View		
Areas	Solids	Links	
Labels	🗖 Labels	🗖 Labels	Apply to All Windows
☐ Sections	🗖 🗖 Sections	Froperties	
📕 Local Axes	Local Axes	🗖 Local Axes	
厂 Not in View	🗖 Not in View	🗖 Not in View	Cancel

#### Step 5-3: Draw Roof Slab

Click on Quick Draw Area Element button, select "TH15CM" and click on roof slab panel area as shown in figure below one by one.



#### Step 5-4: Divide Roof Slab

Click on Set Select Mode button, select all roof slab panels, go to Edit >> Divide Areas....



### Step 5-5: Specify Slab Meshing Size

Divide Selected Areas				
<ul> <li>Divide Area Into This Number of Objects (Quads and Triangles O Along Edge from Point 1 to 2 Along Edge from Point 1 to 3</li> </ul>	Inly)			
C Divide Area Into Objects of This Maximum Size (Quads and Trian Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	igles Only)			
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Triang Points Determined From:</li> <li>Intersections of Visible Straight XY Grid Lines With Area E</li> <li>Intersections of Selected Straight Line Objects With Area</li> <li>Selected Point Objects On Area Edges</li> </ul>	<b>les Only)</b> Idges Edges			
Divide Area Using Cookie Cut Based On Selected Straight Line Ob Extend All Lines To Intersect Area Edges	jects			
O Divide Area Using Cookie Cut Based On Selected Point Objects Rotation of Cut Lines From Area Local Axes (Deg)				
C Divide Area Using General Divide Tool Based On Selected Points Maximum Size of Divided Object	and Lines			
Local Axes For Added Points				
<ul> <li>Make same on Edge if adjacent corners have same local axes definition</li> <li>Make same on Face if all corners have same local axes definition</li> </ul>	nition			
Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent corner p (Applies if added edge point and adjacent corner points have same Add on Face when restraints/constraints exist at all corner points (Applies if added face point and all corner points have same local a	ioints local axes definition)			

# 6. Draw Bottom Slabs

#### Step 6-1: Move Plan View to Bottom Level

Click on  $\clubsuit$  twice to move plan view to the level Z = 0.00.



#### Step 6-2: Draw Bottom Slabs

Click on Draw Rectangular Area Element button, select "TH30CM" and click on two nodes at the corners of bottom slab as shown below.



#### Step 6-3: Mesh Bottom Slabs

Select bottom slabs as shown in figure below and go to Edit >> Divide Areas...



Divide Selected Areas	
Divide Area Into This Number of Objects (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3	Units Ton, m, C
C Divide Area Into Objects of This Maximum Size (Quads and Triangles Only) Along Edge from Point 1 to 2	
<ul> <li>O Divide Area Based On Points On Area Edges (Quads and Triangles Only) Points Determined From:</li> <li>✓ Intersections of Visible Straight XY Grid Lines With Area Edges</li> <li>✓ Intersections of Selected Straight Line Objects With Area Edges</li> <li>✓ Selected Point Objects On Area Edges</li> </ul>	
<ul> <li>Divide Area Using Cookie Cut Based On Selected Straight Line Objects</li> <li>Extend All Lines To Intersect Area Edges</li> </ul>	
C Divide Area Using Cookie Cut Based On Selected Point Objects Rotation of Cut Lines From Area Local Axes (Deg)	
C Divide Area Using General Divide Tool Based On Selected Points and Lines Maximum Size of Divided Object	
Local Axes For Added Points Make same on Edge if adjacent corners have same local axes definition Make same on Face if all corners have same local axes definition	(
Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent corner points (Applies if added edge point and adjacent corner points have same local axes definition) Add on Face when restraints/constraints exist at all corner points (Applies if added face point and all corner points have same local axes definition)	Cancel

#### Step 6-4: Mesh Bottom Slabs

Select bottom slabs as shown below and go to Edit >> Divide Areas...



Divide Selected Areas	
r	
O Divide Area Into This Number of Objects (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3	Ton, m, C
C Divide Area Into Objects of This Maximum Size (Quads and Triangles Only) Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Triangles Only)</li> <li>Points Determined From:         <ul> <li>Intersections of Visible Straight XY Grid Lines With Area Edges</li> <li>Intersections of Selected Straight Line Objects With Area Edges</li> <li>Selected Point Objects On Area Edges</li> </ul> </li> <li>Divide Area Using Conkie Cut Based On Selected Straight I ine Objects</li> </ul>	
Extend All Lines To Intersect Area Edges     Divide Area Using Cookie Cut Based On Selected Point Objects	
Rotation of Cut Lines From Area Local Axes (Deg)	
C Divide Area Using General Divide Tool Based On Selected Points and Lines Maximum Size of Divided Object	
Local Axes For Added Points Make same on Edge if adjacent corners have same local axes definition	
Make same on Face if all corners have same local axes definition	( = = n
Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent corner points (Applies if added edge point and adjacent corner points have same local axes definition) Add on Face when restraints/constraints exist at all corner points	OK Cancel
(Applies if added face point and all corner points have same local axes definition)	

#### Step 6-5: Mesh Bottom Slabs

Again, select bottom slabs as shown below and go to Edit >> Divide Areas...



Divide Selected Areas			
Divide Area Into This Number of Objects (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3			
Divide Area Into Objects of This Maximum Size (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3			
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Triangles Only)</li> <li>Points Determined From:         <ul> <li>Intersections of Visible Straight XY Grid Lines With Area Edges</li> <li>Intersections of Selected Straight Line Objects With Area Edges</li> <li>Selected Point Objects On Area Edges</li> </ul> </li> <li>C Divide Area Using Cookie Cut Based On Selected Straight Line Objects</li> <li>Extend All Lines To Intersect Area Edges</li> </ul>			
Divide Area Using Cookie Cut Based On Selected Point Objects     Rotation of Cut Lines From Area Local Axes (Deg)     Divide Area Using General Divide Tool Based On Selected Points and Lines			
Maximum Size of Divided Object			
Local Axes For Added Points Make same on Edge if adjacent corners have same local axes definition Make same on Face if all corners have same local axes definition			
Hestraints and Constraints For Added Points     Add on Edge when restraints/constraints exist at adjacent corner points     (Applies if added edge point and adjacent corner points have same local axes definition)     Add on Face when restraints/constraints exist at all corner points     (Applies if added face point and all corner points have same local axes definition)			

#### Step 6-6: Mesh Bottom Slabs

K SAP2000 v10.0.1 Advanced - (Untitled) File Edit View Define Bridge Draw Select Assign Analyze Display Design Options Help 🗅 🗃 🖬 😂 🗠 🖓 🔓 🕨 🔎 魚魚魚魚魚 🕅 3d 🦏 🗷 🕫 分析 🕆 🕂 😳 乙 🗸 🔲 エー 🔍 🗖 IN IT In 16-1 2 127 -🔀 X-Y Plane @ Z=0 R × (xxl2) (x:56 xЗ χ4  $\nabla$ • all<sup>‡</sup> A ps clr<sup>k</sup> NR H × 4 k 3 Areas Selected ×13.56 Y1.74 Z0.00 GLOBAL 💌 Ton, m, C

Once again, select bottom slabs as shown below and go to Edit >> Divide Areas...



# 7. Draw Wall Panels

#### Step 7-1: Change View to Elevation View to XZ Plane

Select left window, click on set XZ View button to change view and click on  $\textcircled{1}{2}$  or  $\textcircled{1}{2}$  to move elevation view to Y = 0 m.



#### Step 7-2: Draw Wall Panels

Click on **Quick Draw Area Element** button, select "TH25CM" and draw area to cover wall panel area as shown in figure below.



#### Step 7-3: Mesh Wall Panels

Click on  $\mathbb{R}$ , select the top part of the wall panel as shown in figure below and go to **Edit >> Divide Areas...** 



Divide Selected Areas		
Divide Area Into This Number of Objects (Quads and Trian Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	ngles Only) 5 1	Units Ton, m, C
Divide Area Into Objects of This Maximum Size (uuads an Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	d Triangles Only)	
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Points Determined From:         <ul> <li>Intersections of Visible Straight XY Grid Lines With</li> <li>Intersections of Selected Straight Line Objects With</li> <li>Selected Point Objects On Area Edges</li> </ul> </li> <li>Divide Area Using Cookie Cut Based On Selected Straight Line Extend All Lines To Intersect Area Edges</li> </ul>	<b>Triangles Only)</b> Area Edges n Area Edges ine Objects	
<ul> <li>Divide Area Using Cookie Cut Based On Selected Point Obj Rotation of Cut Lines From Area Local Axes (Deg)</li> <li>Divide Area Using General Divide Tool Based On Selected Maximum Size of Divided Object</li> </ul>	ects Points and Lines	
Local Axes For Added Points Make same on Edge if adjacent corners have same local ax Make same on Face if all corners have same local axes defi	ies definition nition	(
Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent c (Applies if added edge point and adjacent corner points have Add on Face when restraints/constraints exist at all corner p (Applies if added face point and all corner points have same	orner points e same local axes definition) ioints local axes definition)	OK Cancel

#### Step 7-4: Mesh Wall Panels

Select bottom wall panels as shown in above figure and go to Edit >> Mesh Area.



vide Selected Areas	
Divide Area Into This Number of Objects (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3	Units Ton, m, C
C Divide Area Into Objects of This Maximum Size (Quads and Triangles Only)	• •
Along Edge from Point 1 to 2	
Along Edge from Point 1 to 3	
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Triangles Only)</li> <li>Points Determined From:         <ul> <li>Intersections of Visible Straight XY Grid Lines With Area Edges</li> <li>Intersections of Selected Straight Line Objects With Area Edges</li> <li>Selected Point Objects On Area Edges</li> </ul> </li> </ul>	
Divide Area Using Cookie Cut Based On Selected Straight Line Objects           Extend All Lines To Intersect Area Edges	
C Divide Area Using Cookie Cut Based On Selected Point Objects Rotation of Cut Lines From Area Local Axes (Deg)	-
C Divide Area Using General Divide Tool Based On Selected Points and Lines	
Maximum Size of Divided Object	1
Local Axes For Added Points	
Make same on Edge if adjacent corners have same local axes definition	
Make same on Face if all corners have same local axes definition	1
Restraints and Constraints For Added Points	
Add on Edge when restraints/constraints exist at adjacent corner points	
(Applies if added edge point and adjacent corner points have same local axes definition	n) Cancel
Add on Face when restraints/constraints exist at all corner points (Applies if added face point and all corner points have same local even definition)	

#### Step 7-5: Copy Wall Panels

Select all wall panels, go to **Edit >> Replicate** by drawing rectangular selection to cover all wall panels.



Replicate					
Replicate Linear Radial Acrements dx 0. dy 4. dz 0.	Mirror Replicate Options Modify/Show Replicate Options 4 of 4 active boxes are selected Delete Original Objects				
Number 1 OK Cancel					

#### Step 7-6: Change View to Elevation View to YZ Plane

Select left window, click on  $\stackrel{\text{pr}}{\sim}$  Set YZ View button to change view and click on  $\stackrel{\text{tr}}{\sim}$  or  $\stackrel{\text{tr}}{\sim}$  to move elevation view to X = 0 m.



#### Step 7-7: Draw Wall Panels

Click on Quick Draw Area Element button, select "TH25CM" and draw rectangular to cover wall areas as shown in above figure.



#### Step 7-8: Mesh Wall Panels

Click on Set Select Mode button, select top wall panels as shown in figure below and go to Edit >> Divide Areas...



<ul> <li>Divide Area Into This Number of Objects (Quads an Along Edge from Point 1 to 2 Along Edge from Point 1 to 3</li> </ul>	nd Triangles Only) 4 1 I I I I I I I I I I I I I I I I I I
C Divide Area into Bojects of This Maximum Size (Qu Along Edge from Point 1 to 2 Along Edge from Point 1 to 3	radis and Triangles Only) —
C Divide Area Based On Points On Area Edges (Qua Points Determined From: Intersections of Visible Straight XY Grid Line Intersections of Selected Straight Line Object Selected Point Objects On Area Edges C Divide Area Using Cookie Cut Based On Selected St	ds and Triangles Only) as With Area Edges cts With Area Edges rraight Line Objects
Extend All Lines To Intersect Area Edges     Divide Area Using Cookie Cut Based On Selected Po     Rotation of Cut Lines From Area Local Axes (De	pint Objects
C Divide Area Using General Divide Tool Based On Se Maximum Size of Divided Object	lected Points and Lines
Local Axes For Added Points Make same on Edge if adjacent corners have same I Make same on Face if all corners have same local as Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adja (Applies if added edge point and adjacent corner point Add on Eace when restraints/constraints exist at adja	local axes definition kes definition acent corner points ts have same local axes definition)

#### Step 7-9: Mesh Wall Panels

Select bottom wall panels as shown in figure below and go to Edit >> Divide Areas...



Divide Selected Areas	
Divide Area Into This Number of Objects (Quads and Triangles Only)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3	Units Ton, m, C
Bivide Area Into Bejecter of This Maximum Bizer (Quads and Triangles Boly)     Along Edge from Point 1 to 2     Along Edge from Point 1 to 3	
<ul> <li>Divide Area Based On Points On Area Edges (Quads and Triangles Only)</li> <li>Points Determined From:         <ul> <li>Intersections of Visible Straight XY Grid Lines With Area Edges</li> <li>Intersections of Selected Straight Line Objects With Area Edges</li> <li>Selected Point Objects On Area Edges</li> </ul> </li> <li>C Divide Area Using Cookie Cut Based On Selected Straight Line Objects         <ul> <li>Extend All Lines To Intersect Area Edges</li> </ul> </li> </ul>	
<ul> <li>Divide Area Using Cookie Cut Based On Selected Point Objects</li> <li>Rotation of Cut Lines From Area Local Axes (Deg)</li> <li>Divide Area Using General Divide Tool Based On Selected Points and Lines</li> </ul>	
Maximum Size of Divided Object	
Local Axes For Added Points Make same on Edge if adjacent corners have same local axes definition Make same on Face if all corners have same local axes definition	
Restraints and Constraints For Added Points Add on Edge when restraints/constraints exist at adjacent corner points (Applies if added edge point and adjacent corner points have same local axes definition) Add on Face when restraints/constraints exist at all corner points (Applies if added face point and all corner points have same local axes definition)	OK Cancel

#### Step 7-10: Copy Wall Panels

Select all wall panels and go to Edit >> Replicate



Replicate				
Linear Radial	Mirror			
dx 5. dy 0.	Replicate Options Modify/Show Replicate Options 4 of 4 active boxes are selected			
dz 0.	🔲 Delete Original Objects			
Increment Data				
Number 3				
r,				
OK Cancel				

## 8. Define Load Cases

Water load in each tank will be assigned with difference load cases (TANK1, TANK2 and TANK3) for all possible loading condition.

#### Step 8-1: Add Load Case

Go to **Define >> Load Cases**. Then, specify load case name in text box "Load Case" and then click on "Add New Load" for each and every load case as shown in figure below

Туре	Self Weight Multiplier	Auto Lateral Load	Click To: Add New Load
JDEAD		<u> </u>	Modify Load
DEAD LIVE OTHER OTHER OTHER	1 0 0 0		Modify Lateral Load
	0		
	Type DEAD DEAD LIVE OTHER OTHER OTHER OTHER OTHER OTHER	Self Weight Multiplier       DEAD     1       DEAD     1       DEAD     1       DEAD     0       OTHER     0	Self Weight Type     Auto Lateral Load       DEAD     1       DEAD     1       DEAD     1       DEAD     1       DEAD     1       DITHER     0       OTHER     0

# 9. Define and Assign Joint Pattern

A joint pattern is simply a set of scalar values defined at the joints for assigning more complex distributions of temperature and pressure over the structure. Joint patterns by themselves create no loads on the structure. There are two types of joint pattern as described below.

a. X Y, Z Multiplier Method. Type values in the Constant A, B, C and D edit boxes. The pattern value at each selected joint is calculated as Ax+By+Cz+D, where x, y and z are the joint coordinates of the selected joint in the current coordinate system. The units of constants A, B, and C are 1/Length and constant D is unitless. The calculated pattern value is also unitless.

As an example of this assignment method, the following input defines the joint pattern values used to apply a varying soil pressure load on a wall.



b. **Z Coordinate at Zero Pressure and Weight Per Unit Volume Method.** Type Z Coordinate and weight per unit volume (Wt per unit Vol) values in the edit boxes and select a **Restriction** from the drop down list, then click the Add button. If needed, check the Added Uniform Value per Unit Area check box to specify an added uniform value per unit area. The specified Z coordinate is assumed to be in the current coordinate system. The pattern value at each selected joint is calculated as:



Zcoord	=	specified Z coordinate
Z	=	Z coordinate of the selected joint in the current coordinate system
W	=	specified weight per unit volume
Α	=	specified added value per unit area

All appropriate unit conversion factors are used when calculating the pattern value; however, after the pattern value has been obtained, it is thereafter assumed to be unitless.

Note that positive and negative value restrictions can be specified individually for each set of Z coordinates and weight per unit volume in the summation as well as for the final calculated pattern value.

As an example of this assignment method, the following input defines the joint pattern values used to apply a varying soil pressure load on a wall.

#### Step 9-1: Add New Pattern

Go to **Define >> Joint Patterns**, enter pattern name and click on "Add New Pattern Name to add 2 new joint patterns ("SOIL" and "WATER")

Define Pattern Names	
Patterns WATER DEFAULT SOIL WATER	Click to: Add New Pattern Name Change Pattern Name Delete Pattern OK Cancel

#### Step 9-2: Select Only Wall Panels

Activate 3D View Window by clicking on it, go to **Select >> Select >> Area Section** and select "TH25CM" from the list to select only wall panels. Go to **View >> Selection Only** to view only selected element (wall panels)



#### Step 9-3: View and Select Only Wall Panels

After viewing the selected elements only (wall panels), select all elements in 3D view.



#### Step 9-4: Assign Joint Pattern ("SOIL")

Go to **Assign >> Joint Patterns** and specify parameters as shown in figure below. Afterwards, click "OK".

Pattern Name	SOIL
Pattern Assignment Type X,Y,Z Multipliers (Pattern Value) Z Coordinate at Zero Pressure an	:= Ax + By + Cz + D) d Weight Per Unit Volume
Z Coordinate at Zero Pressure and W Z Coordinate Wt per Unit Vol 3.5 1	eight per Unit Volume Restriction Use All
3.5 1	Use All Modify J Delete
Added Uniform Value per Unit Area	0.
Restrictions	Options
	Add to existing values
Use all values	_
<ul> <li>Use all values</li> <li>Zero Negative values</li> </ul>	C Replace existing values

#### Step 9-5: Set View Limit

Go to **View >> Set Limit** and enter "Set Z Axis Limits" as shown in figure below. Afterwards, click "OK".

Set Limits		
Draw Limits on Plane		
¥ 	Choose Plane • XY • YZ • XZ	Cancel
Set X Axis Limits	Set Y Axis Limits	– Set Z Axis Limits ———
Min -0.5	Min -0.5	Min 0.
Max 15.5	Max 4.5	Max 3
Show All	Show All	Show All
		·

#### Step 9-6: Select Wall Panels

Select all shell elements in 3D view.



#### Step 9-7: Assign Joint Pattern ("SOIL")

Go to **Assign >> Joint Patterns** and specify parameters as shown in figure below.

Pattern Data					
Pattern Nar	ne	WATER			
Pattern Assignme	Pattern Assignment Type				
<ul> <li>○ X, Y, Z Multip</li> <li>○ Z Coordinate</li> </ul>	oliers (Pattern Valu at Zero Pressure a	ie = Ax + By + Cz + D) ind Weight Per Unit Volume			
Z Coordinate at Z Z Coordinate	ero Pressure and V Wt per Unit Vol	Veight per Unit Volume Restriction			
3	1.	Use All 🔹 Add			
3 Added Uniform V	1. 'alue per Unit Area	Use All Modify Delete			
Restrictions		Options			
Ose all value	s	Add to existing values			
C Zero Negativ	e values	C Replace existing values			
C Zero Positive	values	C Delete existing values			
OK Cancel					

#### Step 9-8: Clear Z Axis View Limit and Show All Elements

Specify parameters as shown in figure below and go to View >> Show All.

		Choose Plane	OK (
4		• XY	
		CYZ	Cancel
	ו••••	C XZ	
Set X Axis Lim	its S	et Y Axis Limits	Set Z Axis Limits
Min -0.5		Min -0.5	Min 0
		Max 4.5	Max 3.5
Max 15.5			1 S S S S S S S S S S S S S S S S S S S

# 10. Assign Soil and Water Pressure on Wall Panels

Pressure loads are assigned as triangular load using joint pattern. The direction of pressure depends on side of shell element (Positive pressures are directed toward the interior of the element.). In SAP2000, 2 sides of shell element (top and bottom) are represented as face 5 and face 6. Face 5 of shell element is the positive side of local axis 3, shown in blue color arrow. Local axes 1, 2, and 3 are marked with red, white and blue. Water pressures are assigned in the load cases separately for each tank (TANK1, TANK2 and TANK3).

#### Note:

To view local axis of shell element: Go to v	new >> Set Display Options and or
click on Set Display Options button and sele	ect "Local Axes" in Areas

w least avia of shall elements Co to View ... Set Display Ontions and a

Joints	Frames/Cables/Tendons	General	View by Colors of
🗂 Labels	Labels	🔲 Shrink Objects	Objects
🔽 Restraints	E Sections	Extrude View	C Sections
Springs	🗖 Releases	Fill Objects	C Materials
Local Axes	🗖 Local Axes	🔽 Show Edges	C Color Printer
🔽 Invisible	Frames Not in View	🔽 Show Ref. Lines	C White Background, Black Objects
Not in View	Cables Not in View	Show Bounding Boxes	C Selected Groups Select Groups
	Tendons Not in View		
Areas	Solids	Links	
Labels	Labels	🗖 Labels	Apply to All Windows
F Sections	Sections	Froperties	2
✓ Local Axes	Local Axes	Local Axes	
Not in View	Not in View	Not in View	Cancel

# To set color for face of shell element (Area): Go to Options >> Color >> Display



#### Step 10-1: Change to in X-Z Plane at Y = 0.00

Select left window, click on  $\cong$  Set XZ View button and move elevation view to Y = 0 by clicking  $\stackrel{\circ}{\longrightarrow}$  or  $\stackrel{\circ}{\longrightarrow}$ . The location of this elevation is displayed in blue outline in 3D view (right window).



#### Step 10-2: Assign Water Pressure Load to Tank 1 Wall in XZ Plan at Y = 4.00

Select wall panels in tank 1, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



#### Step 10-3: Assign Water Pressure Load to Tank 2 Wall in XZ Plan at Y = 4.00

Select wall panels in tank 2, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



#### Step 10-4: Assign Water Pressure Load to Tank 3 Wall in XZ Plan at Y = 4.00

Select wall panels in tank 3, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



#### Step 10-5: Assign Soil Pressure to All Tank Wall in XZ Plan at Y = 4.00

Soil pressure will be assigned to opposite face of water pressure (face 5). Select wall panels in all tanks, go to **Assign >> Area Load >> Surface Pressure (All)**, select "Add to Existing Loads" options and specify pressure parameters as shown in figure below (Multiplier = Ka x unit weight of soil = 0.6 x 1.8 = 1.08).



Note: For more details on coefficient of active lateral earth pressure (K<sub>a</sub>), please refer the standard book on geotechnical engineering (for example: page 478 of "Foundation Analysis and Design" by Joseph E. Bowles)

#### Step 10-6: Change View to XZ Plan to Y = 4.00

Move elevation view to Y = 4.00 by clicking  $\textcircled{\circ}$  or  $\textcircled{\circ}$ . In this elevation view, face 5 of wall panels faces outside of water tank then water pressure load will be assigned at face 6 (water tank) and soil pressure will be assigned at face 5 (outside tank) by using same parameters as assigned at elevation Y = 4.00.



Step 10-7: Assign Water Pressure Load to Tank 1 Wall in XZ Plan at Y = 0.00

Select wall panels in tank 1, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



#### Step 10-8: Assign Water Pressure Load to Tank 2 Wall in XZ Plan at Y = 0.00

Select wall panels in tank 2, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



Step 10-9: Assign Water Pressure Load to Tank 3 Wall in XZ Plan at Y = 0.00

Select wall panels in tank 3, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below.



#### Step 10-10: Assign Soil Pressure to All Tank Wall in XZ Plan at Y = 0.00

Soil pressure will be assigned to opposite face of water pressure (face 5). Select wall panels in all tanks, go to **Assign >> Area Load >> Surface Pressure (All)**, select "Add to Existing Loads" options and specify pressure parameters as shown in figure below (Multiplier = Ka x unit weight of soil =  $0.6 \times 1.8 = 1.08$ ).



#### Step 10-11: Change to in YZ Plan at X = 0

Select left window, click on  $\square$  and move elevation view to X= 0 by clicking  $\square$  or  $\square$ . In this elevation view, shows face 5 of wall panels is inside tank then water pressure will be assigned in face 5 and soil pressure will be assigned in face 6.



#### Step 10-12: Assign Water and Soil Pressure to Tank 1 Wall in XZ Plan at X = 0

Select wall panels in tank 1, go to **Assign >> Area Load >> Surface Pressure** (All) and specify pressure parameters as shown in figure below to assign pressure load one by one.





Click on to move elevation view, select all wall panels, go to **Assign >> Area Load >> Surface Pressure (All)** and specify pressure parameters as shown in figure below to assign pressure load one by one.



#### Step 10-14: Assign Water Pressure for Tank 2 and 3 in XZ Plan at X = 10

Click on to move elevation view, select all wall panels, go to **Assign >> Area Load >> Surface Pressure (All)** and specify pressure parameters as shown in figure below to assign pressure load one by one.





Click on to move elevation view, select all wall panels, go to **Assign >> Area Load >> Surface Pressure (All)** and specify pressure parameters as shown in figure below to assign pressure load one by one.



# 11. Assign Load on Top and Bottom Slabs

#### Step 11-1: Assign Live Load on Top Slabs (Z = 3.5)

Change view to XY plan at Z = 3.5 by clicking on  $\sim$  Set XY View button and move plan level to Z = 3.50 by clicking on  $\sim$ . Select all slab panels, go to **Assign >>** Area Loads >> Uniform (Shell) and specify parameters as shown in figure below.



Step 11-2: Assign Water Pressure in Bottom Slabs at Tank 1 (Z = 0.0)

Click on 2 to Z = 0, Select bottom slabs of tank 1, go to **Assign >> Area Loads >> Uniform (Shell)** and specify parameters as shown in figure below.



Note: To do slab selection easier, deactivate snap option by deselect - Points and Grid Intersections button

#### Step 11-3: Assign Water Pressure in Bottom Slabs at Tank 2 (Z = 0.0)

Select bottom slabs of tank 2, go to **Assign >> Area Loads >> Assign >> Area Loads >> Uniform (Shell)** and specify parameters as shown in figure below.



#### Step 11-4: Assign Water Pressure in Bottom Slabs at Tank 3 (Z = 0.0)

Select bottom slabs of tank 3, go to **Assign >> Area Loads >> Uniform (Shell)** and specify parameters as shown in figure below.



#### Step 11-5: Assign Soil Pressure on Cantilever Slabs (Z = 0.0)

Select cantilever slabs, go to **Assign >> Area Loads >> Uniform (Shell)** and specify parameters as shown in figure below.



**Note:** Soil Pressure =  $(3.50 - 0.30/2 + 0.15/2) \times 1.8 = 6.165 \text{ ton/m}^2$ 

#### Step 11-6: Assign Uplift Pressure in Bottom Slabs (Z = 0.0)

Select all slabs, go to **Assign >> Area Loads >> Uniform** and specify parameters as shown in above figure. Negative value is assigned for "Gravity" direction.



Note: Soil Pressure = 3.50 + 0.30/2 + 0.15/2 = 3.725 ton/m<sup>2</sup>

# 12. Assign Spring Support

### Vertical Spring (Z Direction)

Vertical spring support can be calculated from length and cross section of pile as shown in following details.

Area (A)	= 455	cm <sup>2</sup>
Length (L)	= 20	m
Modulus of Concrete (E <sub>c</sub> )	= 253,150	kg/cm <sup>2</sup>
K (Vertical) = $2 \times E \times A / L$	= 2 x 253,150 x	455 / 2000
	= 115,183	kg/cm

#### Horizontal Spring (X and Y Direction)

Horizontal spring support will be assigned as line spring using dummy frame element (30 x 30 cm) and can be calculated from contact area between soil and foundation as shown in following detail

Foundation Depth (D)	= 0.30	m
Modulus of Subgrade Reaction ( $K_S$ )	= 500	T/m²/m
K (Horizontal) = D x $K_s$	= 500 x	0.3
	= 150	T/m/m

Note: 1. The soil restraints on side walls have not been included. If the lateral soil restraint and water pressure are applied together the moment on the side walls will be less than when tank has water without back fill.

2. For more details on modulus of subgrade reaction ( $K_s$ ), please refer the standard book on geotechnical engineering (for example: page 405 of "Foundation Analysis and Design" by Joseph E. Bowles)

#### Step 12-1: Select Nodes at Pile Location to Assign Vertical Springs

Select working unit = "kg, cm", activate snap option by clicking on *He Points and Grid Intersections* button and select support nodes by clicking on nodes at pile location as shown in above figure.



#### Step 12-2: Assign Vertical Springs

Go to **Assign >> Joint >> Springs** and specify parameters as shown in above figure.

Joint Springs			
Spring Direction	LOBAL		
Spring Stiffness			
Translation Global $ imes$	0.		
Translation Global 1'	0		
Tr <u>ans</u> lat <u>ion</u> Global Z	115183		
Rotation about Global $\times$	0.		
Rotation about Global Y	0.		
Rotation about Global Z	0.		
Options			
Add to Existing Sprin	gs		
<ul> <li>Replace Existing Springs</li> </ul>			
C Delete Existing Springs			
Advanced OK Cancel			

Step 12-3: Add "DUMMY" Frame Section

Go to **Define >> Frame Sections...**, select "Add Rectangular" from second dropdown menu. Click "Add New Property..." and specify parameters as shown in figure below.

Frame Properties	
Properties Type in property to find: W8X10 W8X24 W8X26 W8X26 W8X26 W8X26 W8X26 W8X26 W8X27 W8X26 W8X27 W8X26	Rectangular Section
W10x12 W10x68 W10x68 W10x88 W10x12 W12x14 W12x14 W12x14 W12x14 W12x14 W12x14 W12x14 W10x12 W12x14 W10x12 W10x12 W10x12 W10x12 W10x12 W10x12 W10x12 W10x12 W10x68 W1	Section Name DUMMY
	Dimensions         2           Width (12)         30
	Display Color Display Color Concrete Reinforcement

**Note:** The beam does not exist in the tank in reality. The beam is defined only for the propose of applying lateral soil restraints. The dimensions of this beam are assumed based on the thickness of the base slab (30 cm).

#### Step 12-4: Draw "DUMMY" Frame Section

Click on N Draw Frame/Cable Element button, select "DUMMY" and draw frame section as shown in figure below.



#### Step 12-5: Assign Horizontal Springs

Change working unit to "Ton, m", click on Set Select Mode button, select "DUMMY" frames as shown in above figure, go to **Assign >> Frame/Cable/Tendon >> Line Springs** and specify parameter as shown in figure below.



#### Step 12-6: Apply Automatic Frame Mesh to "DUMMY" Frames

Select all "DUMMY" frames by clicking on B Get Previous Selection button, go to **Assign >> Frame/Cable/Tendon >> Automatic Frame Mesh** and specify parameters as shown in figure below.



# **13. Define Load Combinations**

Envelop option is used in load combination ("WATER") to find maximum and minimum results among of all possible full or empty water in each tank. Load combination details (without sanitary durability coefficient) are summarized in following table.

Load Combination Name	Combination Type	Combination Details
TANK120	Linear Add	TANK1 + TANK2
TANK023	Linear Add	TANK2 + TANK3
TANK103	Linear Add	TANK1 + TANK3
TANK123	Linear Add	TANK1 + TANK2 + TANK3
WATER	Envelope	TANK1, TANK2, TANK3, TANK120, TANK023, TANK103, TANK123
DESIGN1	Linear Add	1.4 DEAD + 1.7 WATER
DESIGN2	Linear Add	1.2 DEAD + 1.7 WATER + 1.6 LIVE +1.7 SOIL
DESIGN3	Linear Add	1.2 DEAD + 1.7 WATER + 1.6 LIVE +1.7 SOIL + 1.7 UPLIFT
DESIGN4	Linear Add	1.2 DEAD + 1.0 LIVE
DESIGN5	Linear Add	0.9 DEAD + 1.7 SOIL + 1.7 UPLIFT

#### Step 13-1: Add New Load Combination

Go to Define >> Combinations and click on "Add New Combo"

Define Response Combination	s
Combinations	S Click_to: Add New Combo Modify/Show Combo Delete Combo
	Cancel

#### Step 13-2: Define Load Combination

Specify "Name", select "Combination Type", enter load and scale factor and click on "Add" to define load combination as shown in abovementioned table.

Response Combine	ation Data		
Response (	Combination Name	Сомв1	
Combination 1	Гуре	Lin	ear Add 👤
Define Combination	n of Case Results		
Case Name	Case Type	Scale Factor	
TANK1 💌	Linear Static	1.	
TANK1	Linear Static	1.	Add
		L.	
	+		Modify
			Delete
		Cancel	



Define Response Combinations	
Combinations TANK120 TANK023 TANK103 TANK123 WATER DESIGN1 DESIGN2 DESIGN3 DESIGN4 DESIGN5	Click to: Add New Combo Modify/Show Combo Delete Combo

# 14. Run Analysis

#### Step 14-1: Start Analysis

Go to **Analyze > Run Analysis** or click on **P** *Run Analysis* button and click on "Run Now" button to start analysis and wait until analysis process complete.

Set Analysis Cases	to Run			
Case Name DEAD MODAL LIVE TANK1	Type Linear Static Modal Linear Static Linear Static	Status Not Run Not Run Not Run Not Run	Action Run Run Run Run	Run/Do Not Run Case
TANK2 TANK3 SOIL UPLIFT	Linear Static Linear Static Linear Static Linear Static	Not Hun Not Run Not Run Not Run	Hun Run Run Run	Delete Results for Case Run/Do Not Run All
			-	Delete All Results
	Run Now	Show Analysis Case		Cancel

🔀 SAP Analysis Monitor	
File Name:         G:\temp\watertank-under01.sdb           Start Time:         11/22/2006 12:39:08         Ela           Finish Time:         11/22/2006 12:39:16         Ruit	psed Time: 00:00:08 n Status: Done - Analysis Complete
FREQUENCY SHIFT (CENTER) (CYC/TIME) FREQUENCY CUTOFF (RADIUS) (CYC/TIME) ALLOW AUTOMATIC FREQUENCY SHIFTING	= .000000 = -INFINITY- = NO
Found mode         1 of         12:         EV= 4.068           Found mode         2 of         12:         EV= 1.152           Found mode         3 of         12:         EV= 1.287           Found mode         4 of         12:         EV= 4.305           Found mode         5 of         12:         EV= 4.305           Found mode         6 of         12:         EV= 4.305           Found mode         6 of         12:         EV= 4.305           Found mode         6 of         12:         EV= 9.310           Found mode         6 of         12:         EV= 9.310           Found mode         8 of         12:         EV= 4.739           Found mode         9 of         12:         EV= 5.217           Found mode         9 of         12:         EV= 5.217           Found mode         9 of         12:         EV= 5.217           Found mode         10 of         12:         EV= 5.467           Found mode         10 of         12:         EV= 7.167           Found mode         10 of         12:         EV= 7.665           Found mode         12 of         12:         EV= 9.084	6060E+01, f= 1.015180, T= 0.985047 4402E+02, f= 1.708556, T= 0.585289 4830E+02, f= 1.805888, T= 0.553744 8909E+03, f= 10.443634, T= 0.095752 7481E+03, f= 13.483860, T= 0.074163 0509E+03, f= 15.356638, T= 0.065118 9476E+04, f= 34.650292, T= 0.028860 0111E+04, f= 36.352226, T= 0.027509 5023E+04, f= 37.214708, T= 0.026871 0636E+04, f= 42.607962, T= 0.023470 4771E+04, f= 44.064589, T= 0.022694 2357E+04, f= 47.969405, T= 0.020847
NUMBER OF EIGEN MODES FOUND NUMBER OF ITERATIONS PERFORMED NUMBER OF STIFFNESS SHIFTS	= 12 = 13 = 0
ANALYSIS COMPLETE	2006/11/22 12:39:15

#### Step 14-2: Complete Analysis

Wait until analysis status window display "ANALYSIS COMPLETE".

# 15. View Analysis Results

Forces and stresses in shell element for slabs, walls and footing can be displayed in color contour. To use these results for design, sanitary durability coefficients need to be applied as following details.

Reinforcement in Flexure	= 1.3 U
Direct Tension/Hoop Reinforcement	= 1.6 U
Excess Shear (for Stirrup)	= 1.3 U
Compression + Flexure	= 1.0 U
**U = Load Combination	



PLATE BENDING AND TWISTING MOMENTS

The direction and sign convention of forces/ stresses in shell element are described in "SAP2000 Analysis Reference Manual" page 131 to page 151 that is available in PDF format (file name "SapRefer.pdf") located at the "Manual" subfolder in folder that SAP2000 has been installed in your computer.

#### How to Compute Reinforcement from Finite Element Output



The direction of reinforcement for M11 and M 22 are as shown in left figure,

Step 15-1: Select Shell Analysis Results to View in Graphic

Go to Display >> Forces/Stresses >> Shells and select desired result parameters

Case/Combo	Component Type C Resultant Forces Shell Stresses Shell Layer Stresses C Concrete Design
Multivalued Options C Envelope Max C Envelope Min Step 1	Component           C F11         • M11         C V13           C F22         C M22         C V23           C F12         C M12         C VMax           C FMax         C MMax           C FMin         C MMin
Min 0. Max 0. Set To Default Contour Range	C FVM
None     At All Joints     Over Objects and Groups     Set Groups  Miscellaneous Options	
Show Continuous Contours (Enhanced Graphics)	Cancel

Reinforcement Design for M22

#### Step 15-2: View Shell Analysis Results in Contour

Forces/Stresses in shell elements are displayed in contour color. Color tab at the bottom of screen indicates the value range of the results.



#### Step 15-3: Select Shell Analysis Results to View in Tabular Form

Forces/Stresses in shell elements are displayed in tabular form. Go to **Display** >> **Show Table**. Select "Area Output", click on "Select Analysis Cases" to select desired load cases and combinations

Choose Tables for Display	
Edit	
<ul> <li>MODEL DEFINITION (0 of 65 tables selected)</li> <li>System Data</li> <li>Property Definitions</li> <li>Load Definitions</li> <li>Other Definitions</li> <li>Analysis Case Definitions</li> <li>Bridge Data</li> <li>Connectivity Data</li> <li>Joint Assignments</li> <li>Frame Assignments</li> <li>Area Assignments</li> <li>Miscellaneous Data</li> <li>Miscellaneous Data</li> <li>Miscellaneous Data</li> <li>Structure Output</li> <li>Table: Element Forces - Area Shells</li> <li>Table: Element Stresses - Area Shells</li> <li>Structure Output</li> </ul>	Load Cases (Model Def.) Select Load Cases 7 of 7 Selected Analysis Cases. (Results) Select Analysis Cases 10 of To Selected Modify/Show Options Options Selection Only Selection Only Selection Only Show Unformatted Named Sets Save Named Set Delete Named Set Delete Named Set
Table Formats File Current Table Formats File: Program Default	

#### Step 15-4: View Shell Analysis Results to View in Tabular Form

Shell analysis results are displayed in tabular form as shown in figure below.

s: As Noted		Element Forces - Area Shells						
Area Text	AreaElem Text	ShellType Text	Joint Text	OutputCase Text	CaseType Text	StepType Text	F11 Ton/m	F22 Ton/m
5	1	Shell-Thin	5	TANK120	Combination		-0.842	0.659
5	1	Shell-Thin	13	TANK120	Combination		-0.89	0.417
5	1	Shell-Thin	14	TANK120	Combination		-0.332	0.529
5	1	Shell-Thin	15	TANK120	Combination		-0.283	0.771
5	1	Shell-Thin	5	TANK023	Combination		-0.103	0.395
5	1	Shell-Thin	13	TANK023	Combination		-0.15	0.157
5	1	Shell-Thin	14	TANK023	Combination		-0.219	0.144
5	1	Shell-Thin	15	TANK023	Combination		-0.172	0.381
5	1	Shell-Thin	5	TANK103	Combination		-0.677	0.006977
5	1	Shell-Thin	13	TANK103	Combination		-0.645	0.168
5	1	Shell-Thin	14	TANK103	Combination		0.038	0.304
5	1	Shell-Thin	15	TANK103	Combination		0.006183	0.144
5	1	Shell-Thin	5	TANK123	Combination	1	-0.81	0.531
5	1	Shell-Thin	13	TANK123	Combination		-0.842	0.371
5	1	Shell-Thin	14	TANK123	Combination		-0.256	0.488
5	1	Shell-Thin	15	TANK123	Combination		-0.224	0.648
5	1	Shell-Thin	5	WATER	Combination	Max	0.031	0.659
5	1	Shell-Thin	13	WATER	Combination	Max	0.048	0.417
5	1	Shell-Thin	14	WATER	Combination	Max	0.076	0.529
5	1	Shell-Thin	15	WATER	Combination	May	0.059	0 771