

## Problem U

### Barrel Vaulted Structure

#### Concrete

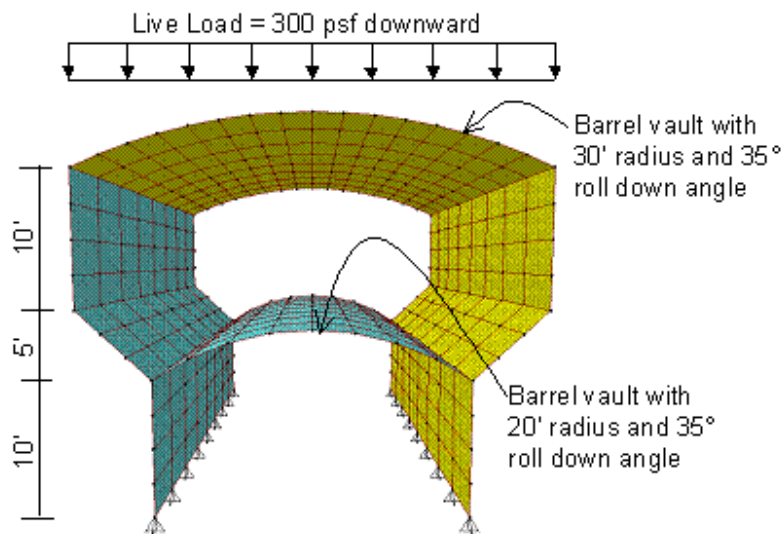
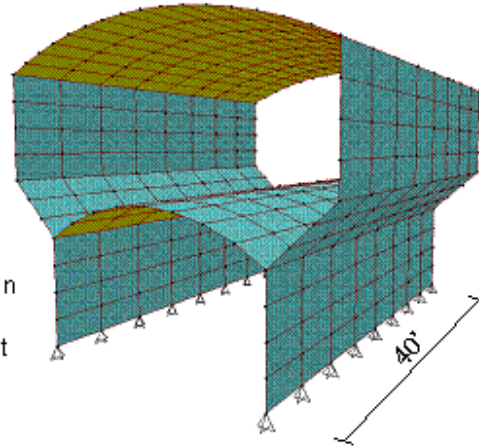
$E = 3600$  ksi

Poissons Ratio = 0.2

12" thick concrete walls  
and slabs

#### To Do

Determine the maximum deflection at the center of upper and lower barrel vaults due to the self weight of the structure. Also determine the maximum deflection at center of upper and lower barrel vaults due to the self weight plus the prescribed live load applied to the top barrel vault.



### CSI Solution Demonstrates Use of These Features


- Add To Model From Template
- Response Combinations
- New Model From Template

### Problem U Solution

1. Click the **File menu > New Model** command to display the **New Model** form.

2. Click the drop-down box to the units to .



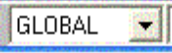
3. Click on the **Shells** button to display the **Shells** form. In that form:
  - Select *Barrel Shell* in the *Shell Type* drop-down list.
  - Accept the default *Number of Divisions, Axial*, 8.
  - Accept the default *Number of Divisions, Angular*, 8.
  - Type **40** in the *Length, L* edit box.
  - Type **35** in the *Roll Down Angle, T* edit box.
  - Type **20** in the *Radius, T* edit box.
  - Uncheck the *Restrains* check box.
  - Click the **OK** button.
4. Click in the 3-D View window to make sure it is active. The window is highlighted when it is active.
5. Click the **Select All** button  on the side toolbar to select the entire structure.
6. Click the **Edit menu > Move** command to display the **Move** form. In that form:
  - Type **10** in the *Delta Z* edit box.
  - Click the **OK** button.
7. Click the **Edit menu > Add To Model From Template** command to display the **New**



**Model** form. In that form click on the **Shells** button to display the **Shells** form. In that form:

- Select *Barrel Shell* in the *Shell Type* drop-down list.
- Accept the default *Number of Divisions, Axial*, 8.
- Accept the default *Number of Divisions, Angular*, 8.
- Type **40** in the *Length, L* edit box.
- Type **35** in the *Roll Down Angle, T* edit box.
- Type **30** in the *Radius, R* edit box.
- Uncheck the *Restrains* check box if it is not already unchecked.
- Click the **Locate Origin** button to display the **Coordinate System** form. In that form:
  - Select the *3D* option.
  - Type **25** in the *Z* edit box in the *Translations* area.
  - Click the **OK** buttons on the **Coordinate System** and **Shells** forms to exit all forms.

8. Click in the Y-Z Plane @ X=-20 window to make sure it is active.

9. Verify that the drop-down list for the Coordinate System shows  on the Status Bar.

10. Click the **Set Display Options** button  (or the **View menu > Set Display Options** command) to display the **Display Options for Active Window** form. In that form:

- Check the *Labels* box in the *Joints* area.
- Click the **OK** button.

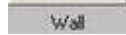
11. Right click on joint 82 in the Y-Z Plane @ X=-20 window. The **Point Information** form is displayed.

12. Highlight the Y-coordinate (-17.2073) and press the Ctrl and the C keys on the keyboard at the same time to copy the value to the clipboard.

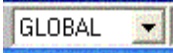
13. Click the **Cancel** button to close the **Point Information** form.

14. Click the **Edit menu > Add To Model From Template** command to display the **New**



**Model** form. In that form click on the **Wall** button  to display the **Shear Wall** form. In that form:

- Type **8** in the *Number of Divisions, X* edit box.
- Type **4** in the *Number of Divisions, Z* edit box.
- Type **5** in the *Division Width, X* edit box.
- Type **2.5** in the *Division Width, Z* edit box.
- Uncheck the *Restraints* check box if it is not already unchecked.
- Click the **Edit Grid** button to display the **Define Grid Data** form. In that form:
  - Click the **Locate System Origin** button to display the **Coordinate System** form. In that form:
    - Select the *3D* option.
    - Highlight the *Y* edit box in the *Translations* area and press the Ctrl and the V keys on the keyboard at the same time to paste the -17.2073 value from the clipboard.
    - Type **15** in the *Z* edit box in the *Translations* area.
    - Click the **OK** buttons on the **Coordinate System, Define Grid Data** and **Shear Wall** forms to exit all forms.

15. Verify that the drop-down list for the Coordinate System shows  on the Status Bar.


16. Right click on joint 1 in the Y-Z Plane @ X=-20 window. The **Point Information** form is displayed.

17. Highlight the Y-coordinate (-11.4715) and press the Ctrl and the C keys on the keyboard at the same time to copy the value to the clipboard.

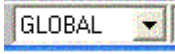
18. Click the **Cancel** button to close the **Point Information** form.

19. Click the **Edit menu > Add To Model From Template** command to display the **New**



**Model** form. In that form click on the **Wall** button  to display the **Shear Wall** form. In that form:

- Type **8** in the *Number of Divisions, X* edit box.
- Type **4** in the *Number of Divisions, Z* edit box.
- Type **5** in the *Division Width, X* edit box.
- Type **2.5** in the *Division Width, Z* edit box.
- Uncheck the *Restraints* check box if it is not already unchecked.
- Check the *Use Custom Grid Spacing* and *Locate Origin* check boxes.
- Click the **Edit Grid** button to display the **Define Grid Data** form. In that form:
  - Click the **Locate System Origin** button to display the **Coordinate System** form. In that form:
    - Select the **3D** option.
    - Highlight the *Y* edit box in the *Translations* area and press the **Ctrl** and the **V** keys on the keyboard at the same time to paste the **-11.4715** value from the clipboard.
    - Click the **OK** buttons on the **Coordinate System, Define Grid Data** and **Shear Wall** forms to exit all forms.

20. Verify that the drop-down list for the Coordinate System shows  on the Status Bar.

21. Click in the **Y-Z Plane @ X=-20** window to make sure it is active.

22. Click the **View menu > Set 2D View** command to display the **Set 2D View** form. In that form:

- Select the *X-Z plane* option.
- Type **-11.4715** in the *Y=* edit box.
- Click the **OK** button.


23. Select all of the objects in this view by “windowing.”


24. Click the **View menu > Set 2D View** command to display the **Set 2D View** form. In that form:

- Select the *X-Z plane* option.
- Type **-17.2073** in the *Y=* edit box.
- Click the **OK** button.

25. Select all of the objects in this view by “windowing.”


26. Click the **View menu > Show Selection Only** command.

27. Click the **Perspective Toggle** button .
28. Click the **View menu > Show Grid** command to toggle the grids off.
29. Click the **View menu > Show Axes** command to toggle the axes off.
30. Click the **Draw menu > Draw Poly Area** command to display the **Properties of Object** form. Verify that *ASEC1* is shown in the *Property* drop-down box.
31. In the X-Z perspective view, click on joints 163, 195, 73 and 1, in that order, and press the Enter key on the keyboard to draw an area object.


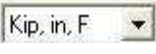
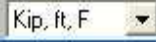
32. Click the **Set Select Mode** button  on the side toolbar to exit Draw mode and enter Select mode.
33. Click on the just drawn area object to select it.
34. Click the **Edit menu > Mesh Areas** command to display the **Mesh Selected Shells** form.





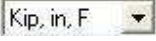

35. Fill in this form as shown in the figure and click the **OK** button.

**Note:** It is difficult to figure out whether to mesh shells 3 by 8 or 8 by 3. It is often easiest to just go ahead and try one way, and if it isn't right, simply click the **Undo** button  and mesh the shells the other way.

36. Select all of the objects in the X-Z perspective view by “windowing.”
37. Click the **Edit menu > Replicate** command to display the **Replicate** form. In that form:
  - Select the *Mirror* Tab.
  - In the *Mirror About Line* area select the *Parallel to Z* option.
  - In the *Intersection of Plane with XY Plane* area, type **0** in the *x1* edit box if it is not already entered.
  - Type **1** in the *x2* edit box.
  - Type **0** in the *y1* edit box if it is not already entered.
  - Type **0** in the *y2* edit box.
  - Click the **OK** button.
38. Click the **View menu > Set 2D View** command to display the **Set 2D View** form. In that form:
  - Select the *X-Y plane* option.
  - Type **0** in the *Z=* edit box if it is not already entered.
  - Click the **OK** button.
39. Select all of the joints at this level by “windowing.”
40. Click the **Assign menu > Joint > Restraints** command to display the **Joint Restraints** form. In that form:
  - Verify that the *Translation 1, 2 and 3* boxes are all checked.
  - Click the **OK** button.

41. Click the **View menu > Set 2D View** command to display the **Set 2D View** form. In that form:
- Select the *Y-Z plane* option.
  - Type **20** in the *X=* edit box.
  - Click the **OK** button.
42. Click the **Show Undeformed Shape** button  to reset the window title.
43. Click the **View menu > Show All** command.
44. Click the drop-down box in the status bar to change the units to .
45. Click the **Define menu > Materials** command to display the **Define Materials** form.
46. Click on **CONC** in the *Materials* area to highlight it (select it), and then click the **Modify/Show Material** button to display the **Material Property Data** form. In that form:
- Verify 3600 is entered in the *Modulus of Elasticity* edit box.
  - Verify 0.2 is entered in the *Poisson's Ratio* edit box.
  - Click the **OK** buttons on the **Material Property Data** and **Define Materials** forms to exit all forms.
47. Click the drop-down box in the status bar to change the units to .
48. Click the **Define menu > Materials** command to display the **Define Materials** form.
49. Click on **CONC** in the *Materials* area to highlight it (select it), and then click the **Modify/Show Material** button to display the **Material Property Data** form. In that form:
- Verify that 4.661E-03 is entered in the *Mass per unit Volume* edit box.
  - Verify that 0.15 is entered in the *Weight per unit Volume* edit box.
  - Click the **OK** buttons on the **Material Property Data** and **Define Material** forms to exit all forms.
50. Click the **Define menu > Area Sections** command to display the **Area Sections** form. In that form:
- Click the **Modify/Show Section** button to display the **Area Section Data** form. In that form:
    - Verify that the *Material Name* is **CONC**.
    - Verify that the *Shell* option is chosen in the *Area Type* area.
    - Verify that both the *Membrane* and *Bending* thicknesses are 1.
    - Verify that the *Shell* option is chosen in the *Type* area.
    - Click the **OK** buttons on the **Area Section Data** and **Area Sections** forms to exit all forms.
51. Click the **Define menu > Load Cases** command to display the **Define Loads** form. In that form:
- Type **LIVE** in the *Load Name* edit box.
  - Select **LIVE** from the *Type* drop-down box.

- Click the **Add New Load** button.
  - Click the **OK** button.
52. Click the **Define menu > Combinations** command to display the **Define Response Combinations** form. In that form:
- Click the **Add New Combo** button to display the **Response Combination Data** form. In that form:
    - Accept the default *Response Combination Name*, COMB1.
    - Accept the default *Combination Type*, Linear Add.
    - Select *DEAD* in the *Case Name* drop-down box (if it is not already selected) and type **1** in the *Scale Factor* edit box (if not already entered).
    - Click the **Add** button.
    - Select *LIVE* in the *Case Name* drop-down box.
    - Click the **Add** button.
    - Click the **OK** buttons on the **Response Combination Data** and **Define Response Combinations** forms to exit all forms.
53. Click in the 3-D View window to activate it. Be careful not to accidentally select any objects when you do this.
54. Click the **View menu > Set Limits** command to display the **Set Limits** form. In that form:
- Type **25** in the *Min* edit box in the *Set Z Axis Limits* area.
  - Click the **OK** button.
55. Select all of the displayed objects in the 3D View window (i.e., all objects in the roof barrel) by “windowing.”
56. Click the **Assign menu > Area Loads > Uniform (Shell)** command to display the **Area Uniform Loads** form. In that form:
- Select *LIVE* from the *Load Case Name* drop-down box.
  - Type **.3** in the *Load* edit box.
  - Verify that *Gravity* is selected in the *Direction* drop-down box.
  - Click the **OK** button.
57. Click the **Show Undeformed Shape** button  to remove the display of area uniform loads and to remove the limits that were set.
58. Click the **Run Analysis** button  to display the **Set Analysis Cases to Run** form. In that form:
- Click on *MODAL* in the *Case Name* list to highlight it.
  - Click the **Run/Do Not Run Case** button.
  - Click the **Run Now** button.

59. When the analysis is complete, check the messages in the **SAP Analysis Monitor** window (there should be no warnings or errors) and then click the **OK** button to close the window.
60. Click in the window entitled 3-D View to activate it.
61. Click the drop-down box in the status bar to change the units to .
62. Right click on the center joint of the upper barrel vault to see its self weight displacement in inches.
63. Right click on the center joint of the lower barrel vault to see its self weight displacement in inches.
64. Click the **Show Deformed Shape** button  to display the **Deformed Shape** form. In that form:
  - Select *COMB1* from the *Case/Combo Name* drop-down box.
  - Click the **OK** button.
65. Right click on the center joint of the upper barrel vault to see its self weight plus live load displacement in inches.
66. Right click on the center joint of the lower barrel vault to see its self weight plus live load displacement in inches.