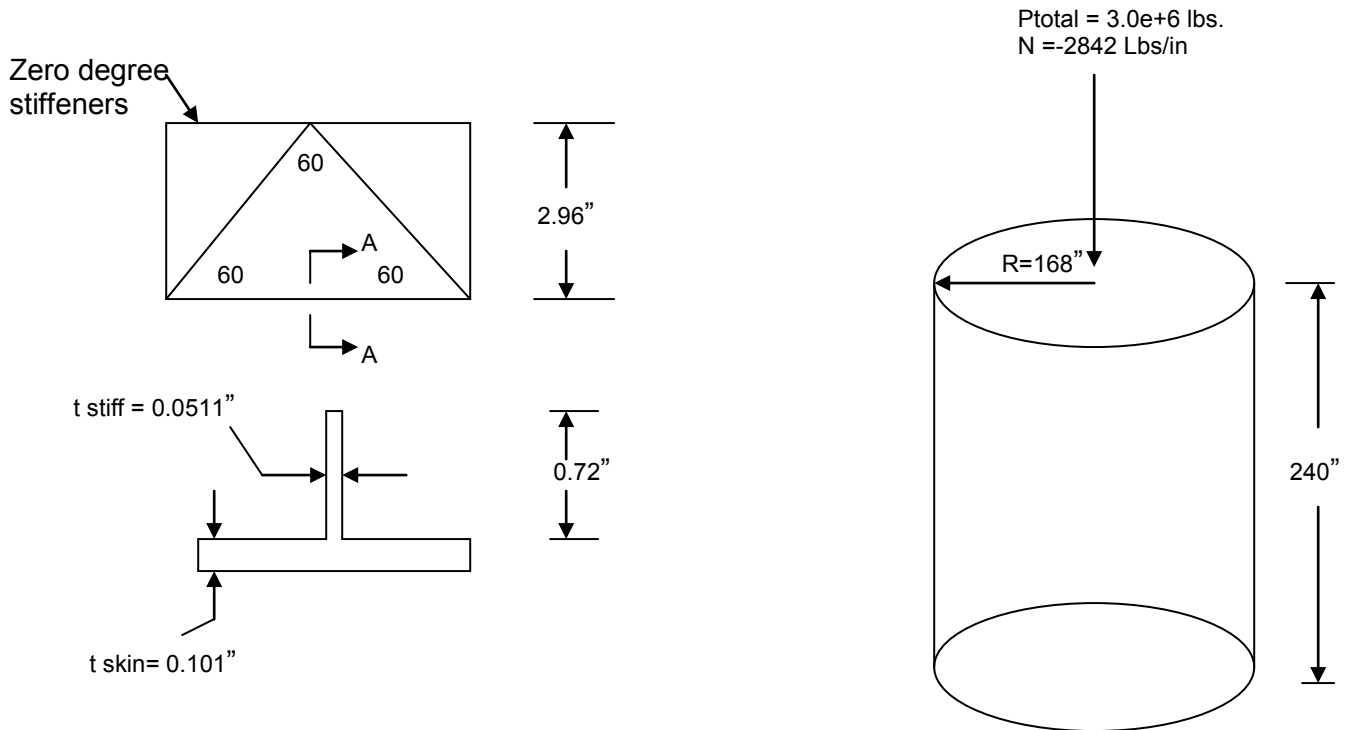
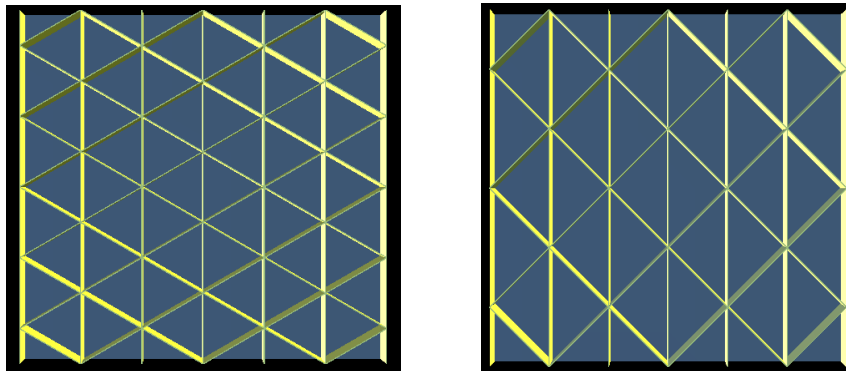


HyperSizer Isogrid Verification



Note: Material is 2219 Aluminum.
 Both angled and zero degree stiffeners are the same thickness(0.0511").
 There are no 90 degree stiffeners.
 Zero degree stiffeners run in circumferential direction.
 Both top and bottom edges of cylinder are clamped.

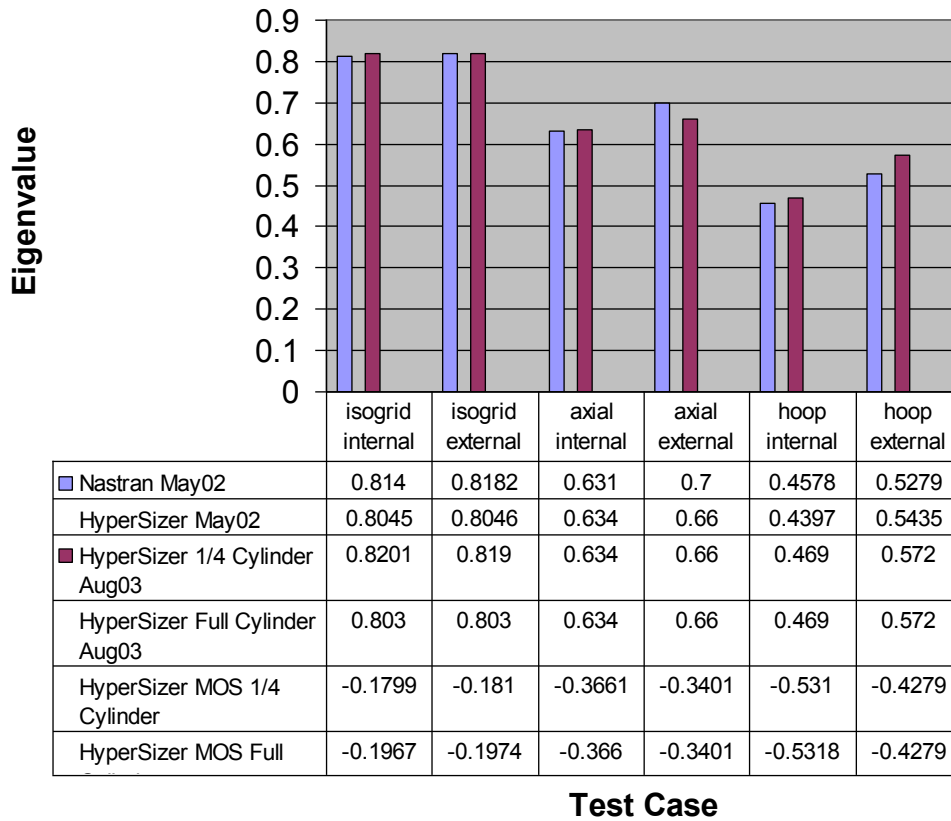
This document summarizes comparisons of compression buckling analyses between HyperSizer and MSC/NASTRAN, for six different cases with stiffeners on the inside and outside of the tank wall (positive and negative curvature), together with combinations of stiffeners primarily oriented in axial stiffness, then in hoop stiffness. All cases compare closely.



The unit weight for the isogrid shown in the left figure is 2.044 (lb/ft²). Using the same dimensions for thickness gages and rib heights, the isogrid was converted to an orthogrid by changing the angle from 30° to 45°. The change in angle causes the panel to have a higher stiffness in one direction. This panel concept is 1.938 (lb/ft²), shown in the right figure. The specifics on the dimensions, loadings, failure margins, etc are contained in the appendix.

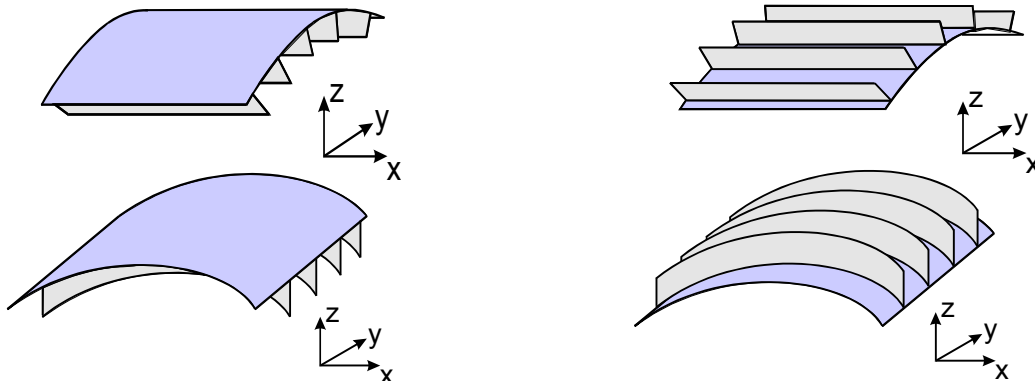
Summary Results

Buckling Comparisons

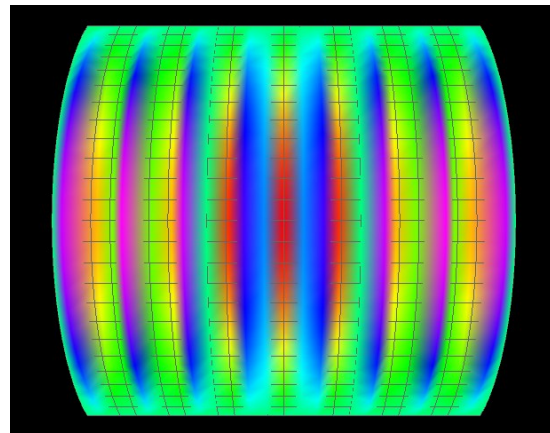
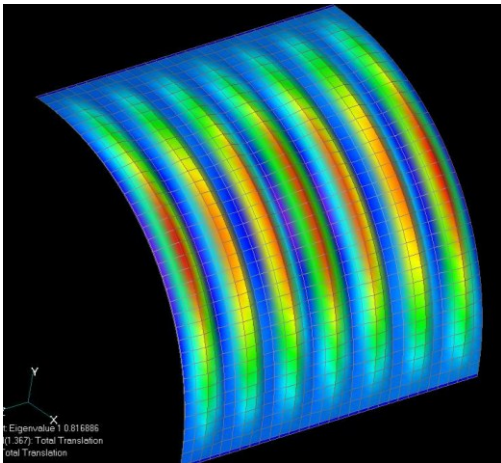
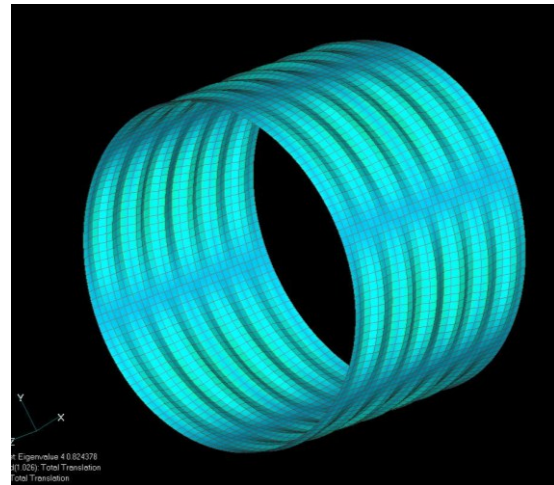
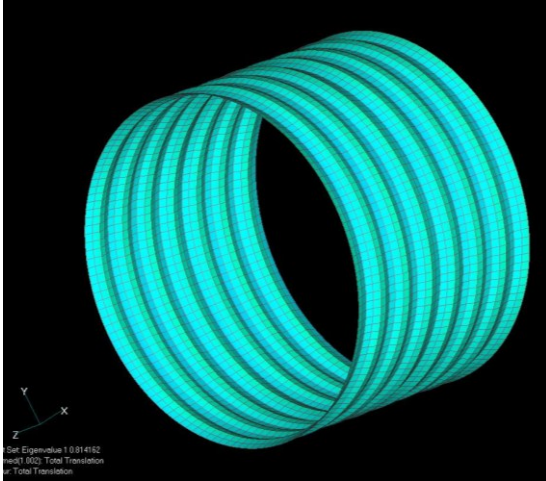
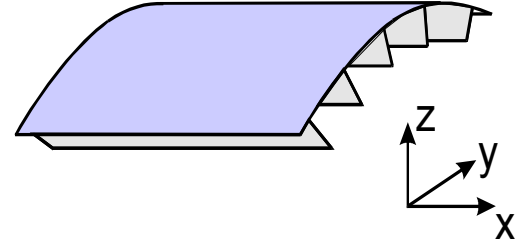


Observations:

1. HyperSizer v 3.5 buckling predictions match well the MSC/NASTRAN v 70.7.2 predictions.
2. It is difficult to achieve the correct solution with the FEA because of boundary condition generality, and care must be exercised to achieve the desired response.
3. The isogrid has the same stiffness in the X(1) and Y(2) directions by definition.
4. The isogrid panel produces nearly the same buckling allowable regardless if the stiffeners are internal (inside) or external (outside) to the shell, for the given $r=168$. For smaller radius of curvatures a more substantial difference was demonstrated by analysis.
5. Four additional possibilities were investigated. These four are represented in the figures below starting from left to right: axial internal, axial external, hoop internal, hoop external.



Case 1: Isogrid panel with stiffeners inside. Since this was the first test case, a full cylindrical FEM was made and compared to the results obtained with a curved panel. The results indicate that all remaining investigations can be carried out with a portion of the cylinder modeled as a curved panel with a width equal to $\frac{1}{4}$ the circumference.



D11=D22, Stiffeners ISOGRID on inside.

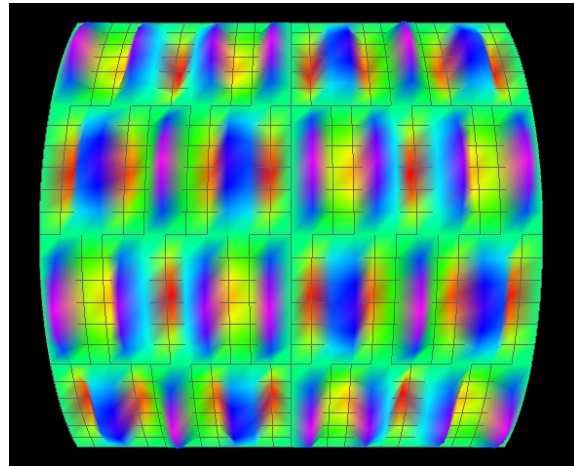
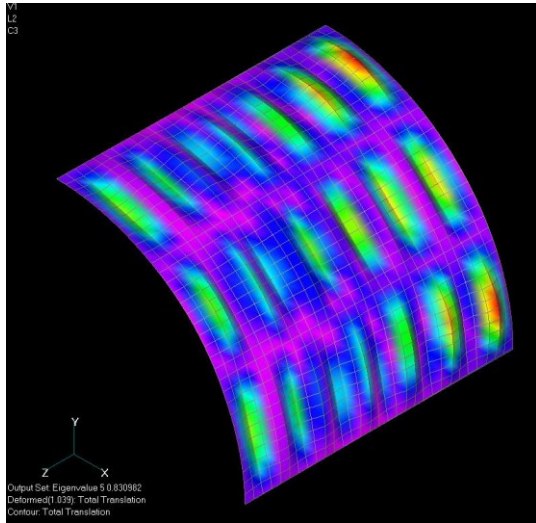
The top two figures: The full cylinder Nastran 1st eigenvalue = 0.814, Nastran 2nd eigv = 0.824. Note that the 2nd mode shape is about the same as the 1st mode shape for the curved panel.

Bottom left figure: Nastran curved panel 1st eigv = 0.817.

Axial = 13 buckling mode waves, hoop = 1 wave

Bottom right figure: HyperSizer for the same mode has an eigv = .8053

Axial = 15 buckling mode waves, hoop = 1 wave



D11=D22, Stiffeners ISOGRID on inside.

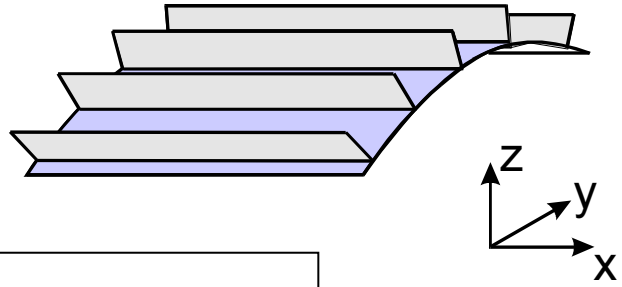
Bottom left figure: The curved panel 5th Nastran eigenvalue = 0.831.

Axial = 15 waves, hoop = 3 waves

Bottom right figure: For a similar mode shape, the 1st HyperSizer eigenvalue = .8045

Axial = 14 waves, hoop = 4 waves

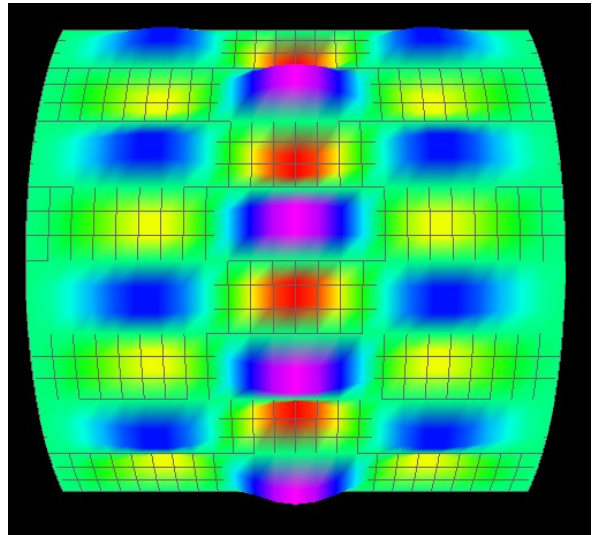
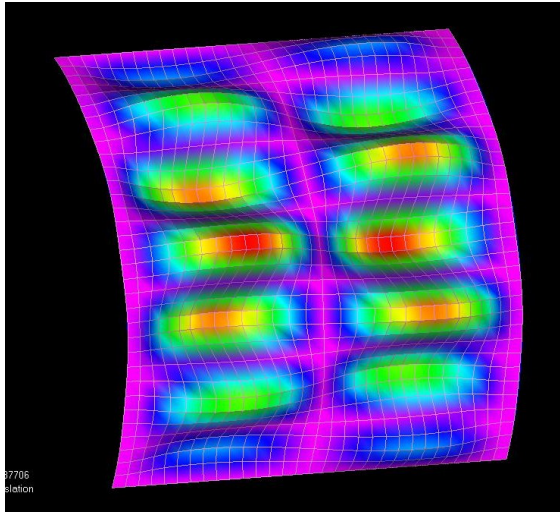
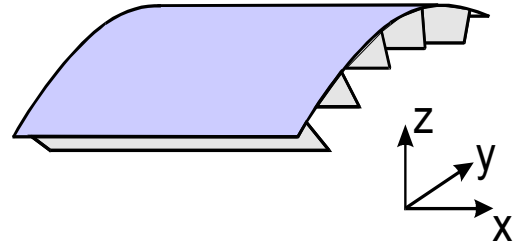
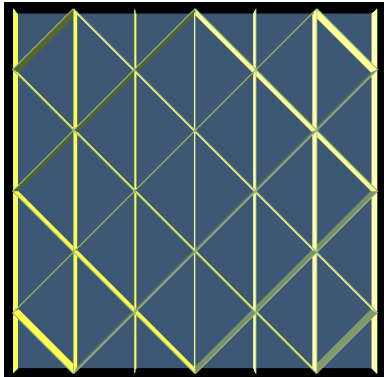
Case 2: Isogrid panel with stiffeners outside. No pictures made, because the mode shapes were very similar to the mode shapes for the previous case of stiffeners on the inside.



D11=D22, Stiffeners ISOGRID on outside.

Nastran eigv 1 = 0.8182, HyperSizer = .8046

Case 3: Orthogrid panel with primary axial stiffeners inside.



Stiffeners primary in AXIAL on inside.

Bottom left figure: Nastran eigv 0.631

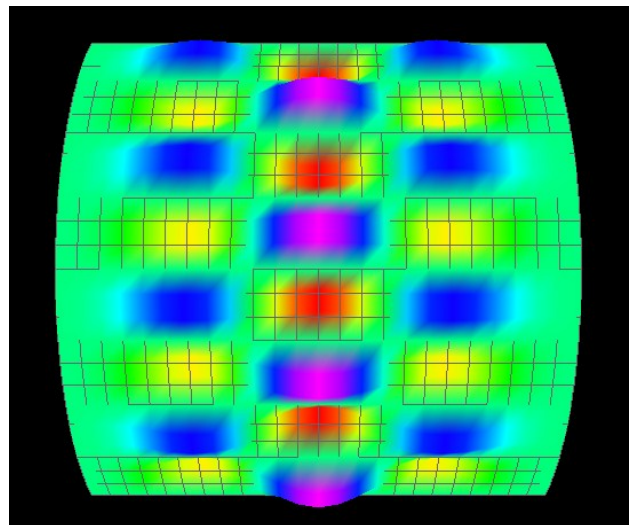
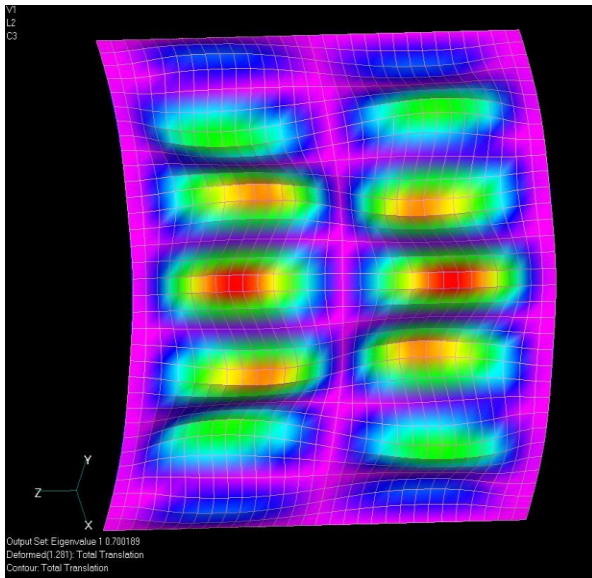
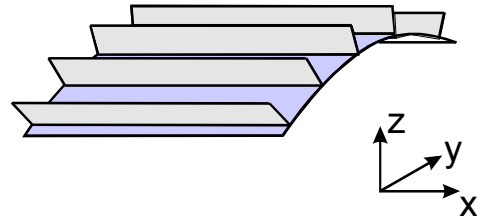
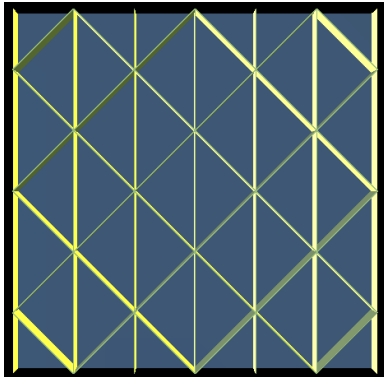
Axial = 2 waves, hoop = 7 waves

**Bottom right figure: HyperSizer MS = -0.3661, Eigv = 0.634,
0.5% unconservative**

Axial = 3 waves, hoop = 8 waves

**displayed the second mode from Nastran, nearly same eigv as
the first mode.**

Case 4: Orthogrid panel with primary axial stiffeners outside.



Stiffeners primary in AXIAL on outside.

Bottom left figure: Nastran eigv 0.7000

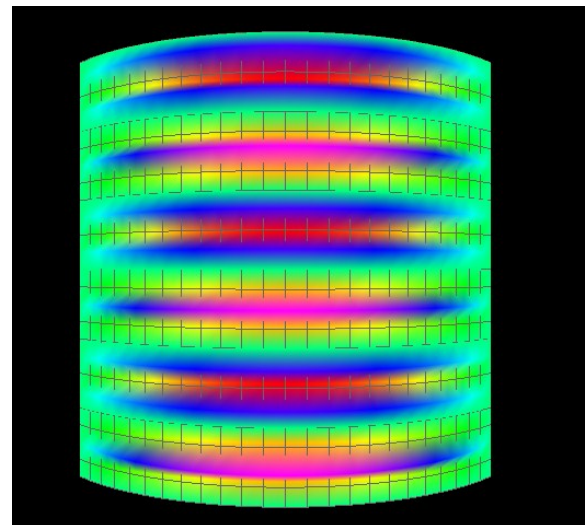
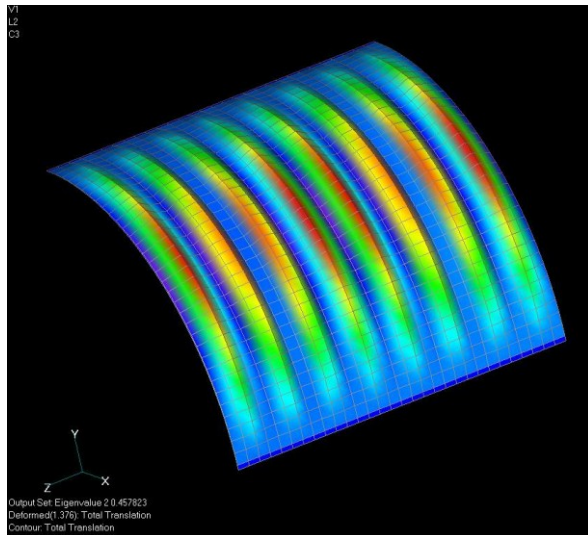
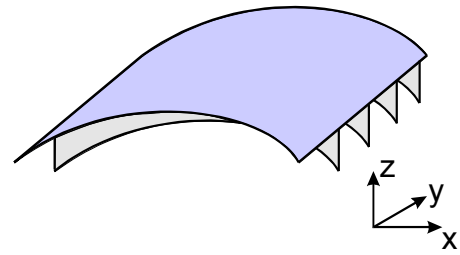
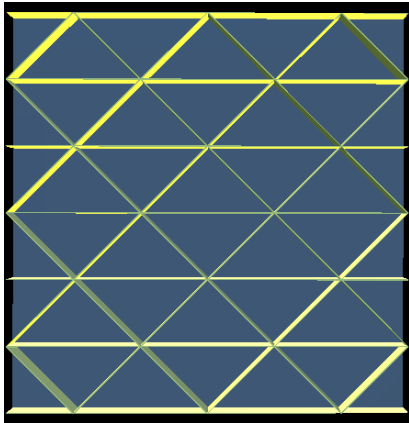
Axial = 2 waves, hoop = 7 waves

Bottom right figure: HyperSizer MS = -0.3401, Eigv = 0.660,

Axial = 3 waves, hoop = 8 waves

6.0% conservative, found a lower energy mode shape, with three waves in axial direction, instead of two.

Case 5: Orthogrid panel with primary hoop stiffeners inside.

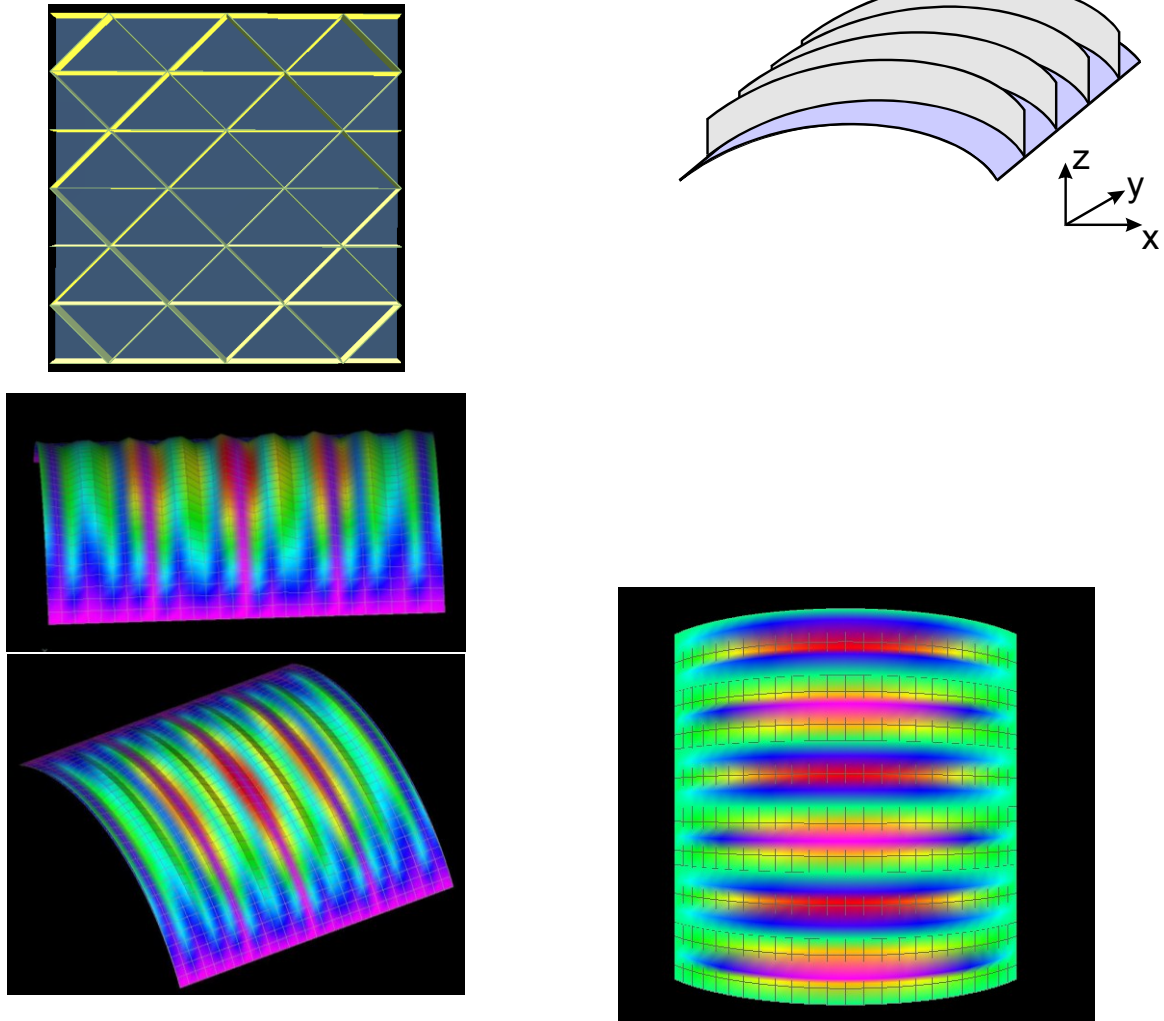


Stiffeners primary in hoop on inside.

**Bottom left figure: Nastran eigv 0.4578,
Axial = 15 waves, hoop = 1 wave**

**Bottom right figure: HyperSizer MS = -0.5603, Eigv = 0.4397,
Axial = 18 waves, hoop = 1 wave
4.1% conservative**

Case 6: Orthogrid panel with primary hoop stiffeners outside.



Stiffeners primary in hoop on outside.

Bottom left figure: Nastran eigv 1 = 0.5279

Axial = 16 waves, hoop = 1 wave

Bottom right figure: HyperSizer MS = -0.4565, Eigv = 0.5435

Axial = 18 waves, hoop = 1 wave

2.9% unconservative. It appears the NASTRAN FEM was too coarse to pick up the modes shapes properly. See in the top figure on left how the buckling modes are less than the typical minimum required of 5 elements.