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UNIVERSITAT POLITÈCNICA DE CATALUNYA, BARCELONA

MSc. COMPUTATIONAL MECHANICS ERASMUS MUNDUS

## ASSIGNMENT 8: SHELLS

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# Computational Structural Mechanics & Dynamics

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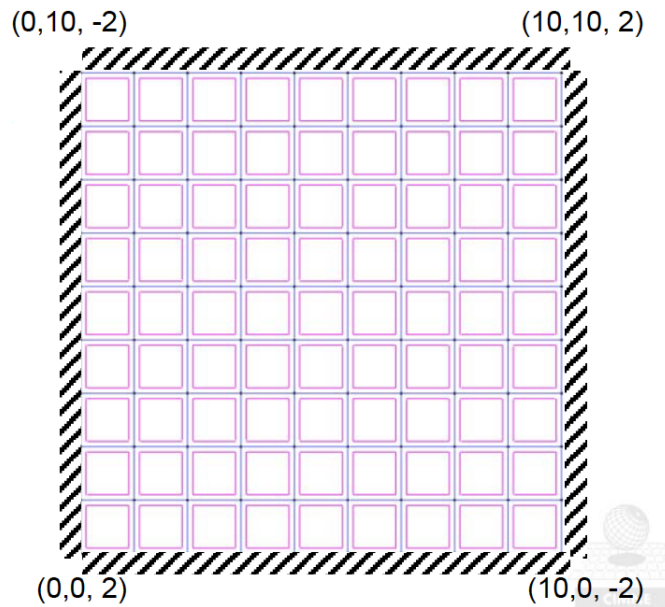
*Author:*

Nikhil Dave

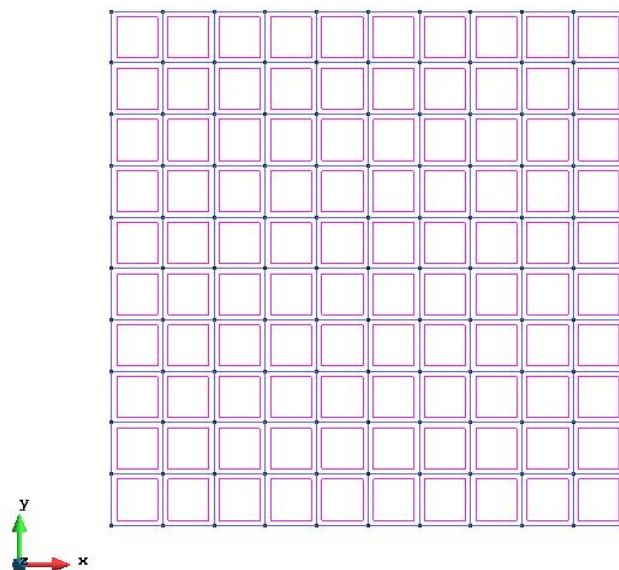
Date: April 15, 2018

**Problem:**

Analyse the following concrete hyperbolic shell under self weight. Explain the behaviour of all the stresses presented. ( $t = 0.1$ )

**Solution:**

For this assignment, the MATLAB program and GiD interface file available at <http://www.cimne.com/mat-fem/shells.asp> is used. Firstly, the geometry definition of the shell is performed in GiD as shown in Figure 1.



**Figure 1:** Geometry of the shell created in GiD

Next, the boundary conditions are applied as shown in Figure 2. In our case, displacement and rotation constraints are applied on the boundary edges of the shell as the given shell is clamped and no forces are considered.

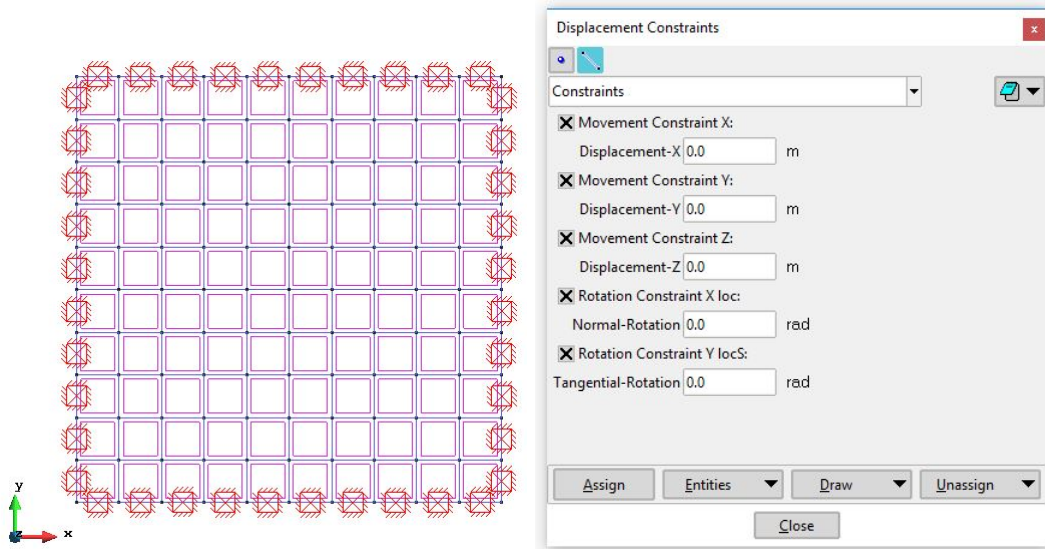


Figure 2: Assigned boundary conditions

The concrete shell is also assigned with the following material properties:

$$E = 3.0e10 \text{ N/m}^2$$

$$\nu = 0.2$$

$$\rho = 2500 \text{ kg/m}^3$$

$$t = 0.1 \text{ m}$$

The assigned material properties and concrete material shell geometry is shown in Figure 3.

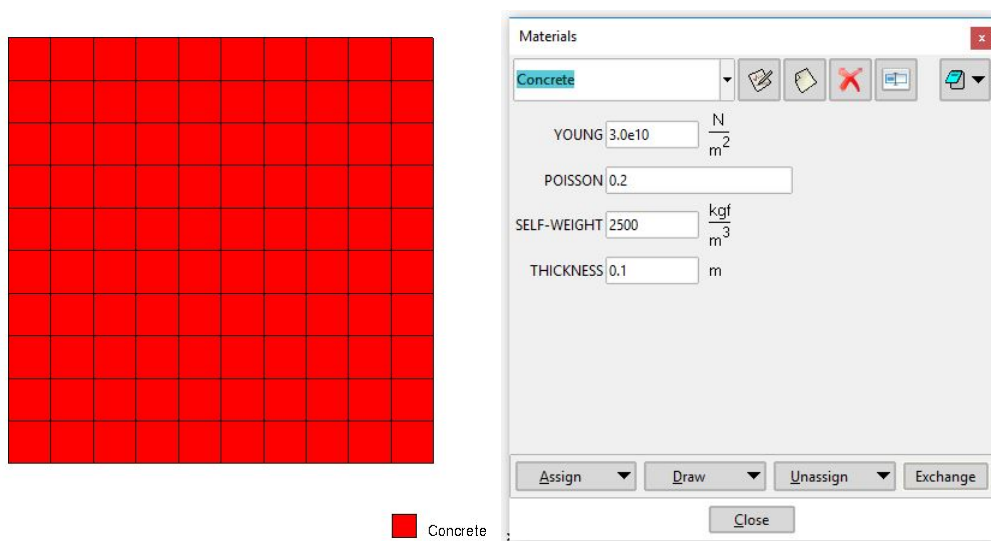


Figure 3: Assigned material properties for the concrete shell geometry

This is followed by assigning the problem data in GiD. In the given problem, the we need to analyse the behaviour of the shell under self weight, therefore self weight is considered in this analysis as shown in Figure 4.

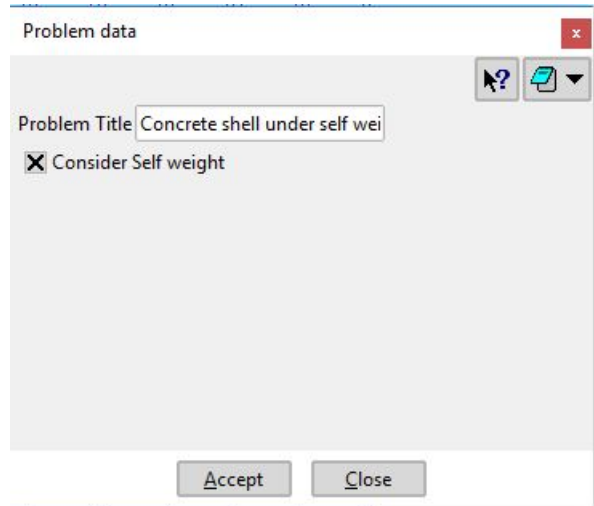


Figure 4: Defined problem data

Now, we generate the mesh for the geometry using 3-noded triangular elements as shown in Figure 5.

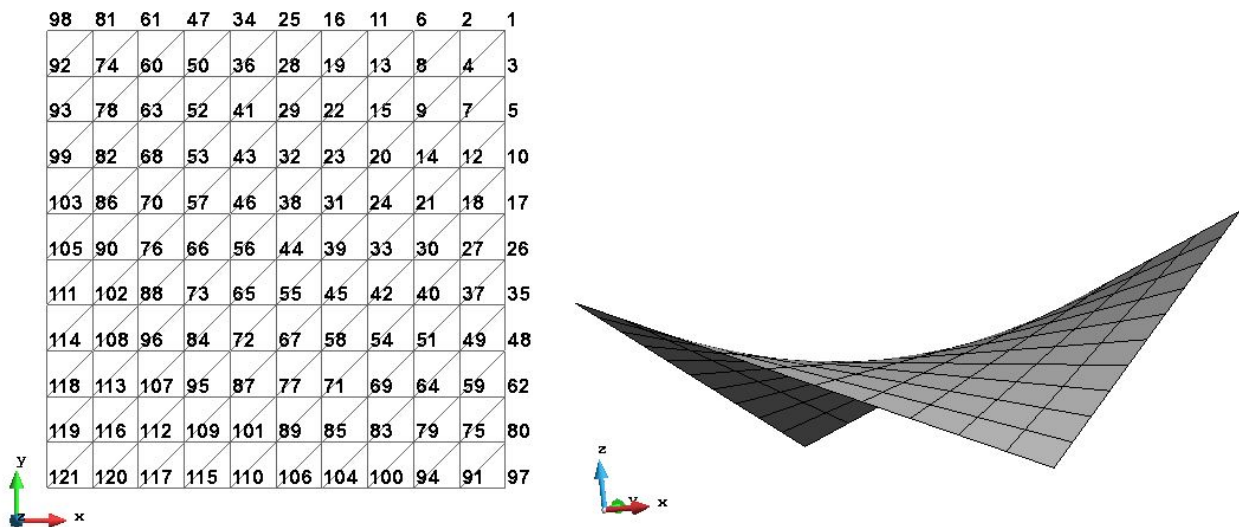
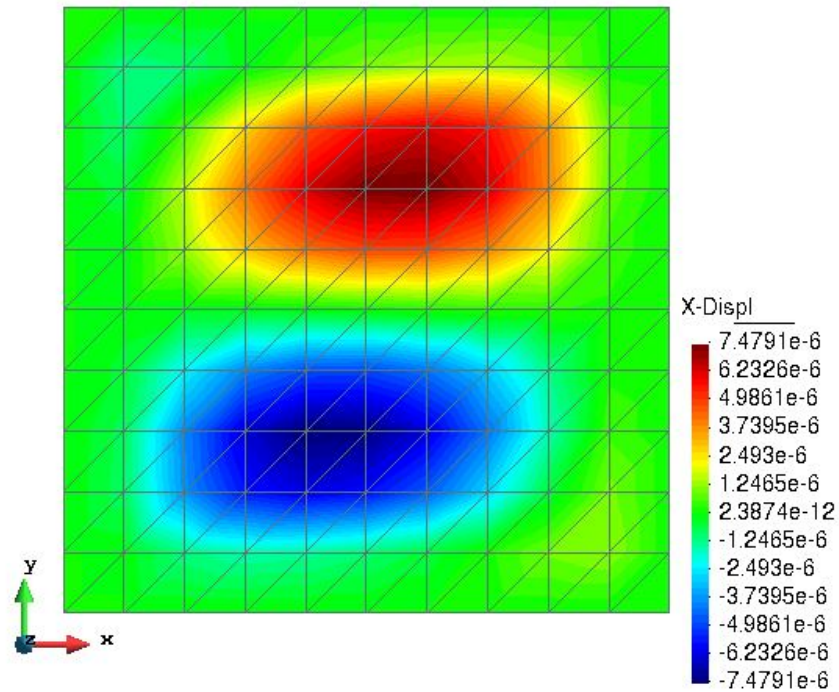


Figure 5: Generated mesh

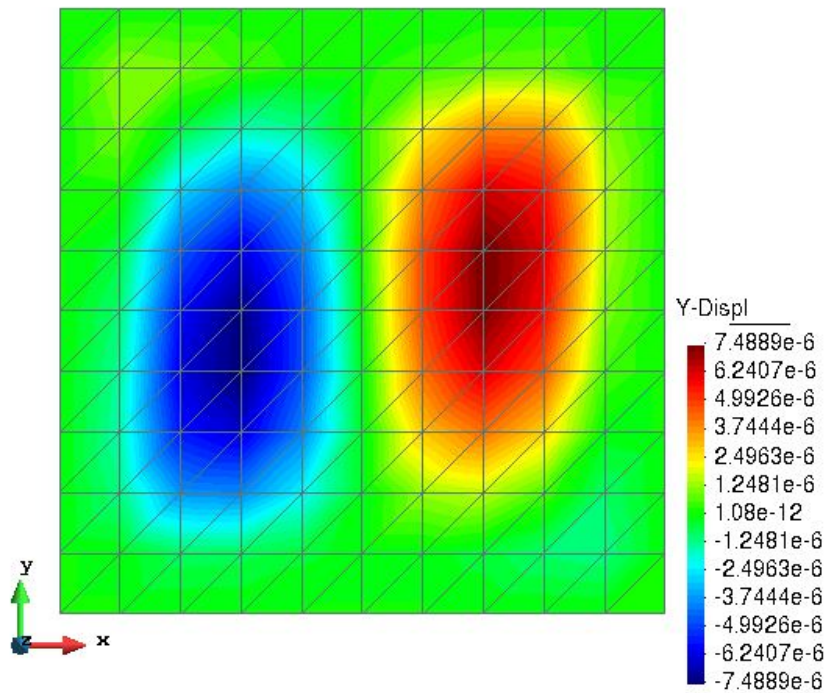
Finally, we can generate the pre-processing file for the given MATLAB program. The *.dat* file generated from GiD is used as an input for the *Shell\_TRM\_v1\_1.m* program. Running this MATLAB solver generates the mesh and results files, *.msh* and *.res*, respectively. These output files are used in the post-processing stage performed in GiD. The post-processed results are shown below.

**Results:**

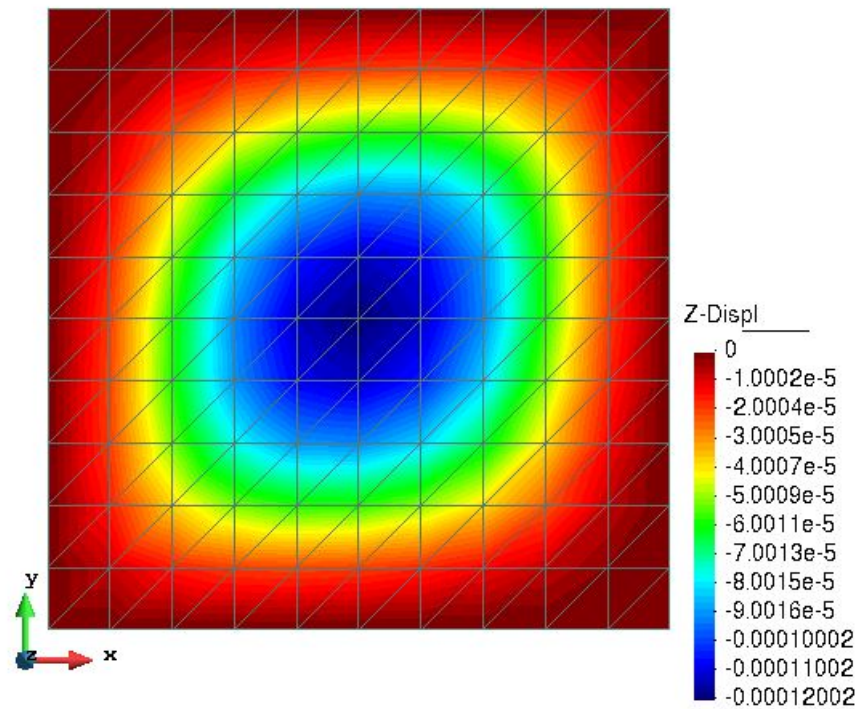
Firstly, Figure 6-8 show the displacements in the  $x$ ,  $y$  and  $z$ -directions, respectively.



**Figure 6:** Displacements in x-direction



**Figure 7:** Displacements in y-direction



**Figure 8:** Displacements in z-direction

The behaviour of the displacements in the above plots is as expected. The effect of the symmetry of the problem can be seen in the  $x$  and  $y$ -displacement results. Since there is no external force applied to the shell, the displacement values in these directions are very small and similar in nature. The effect of considering the self-weight can be seen in the  $z$ -displacement results with maximum deformation in the centre and no displacement on the boundaries.



Next, the rotations of the shell are shown in the Figures 9-10 below. The results in the plots look reasonable as the effect of symmetry is seen again. Also, since the shell is clamped at the boundaries, no rotations are seen there.

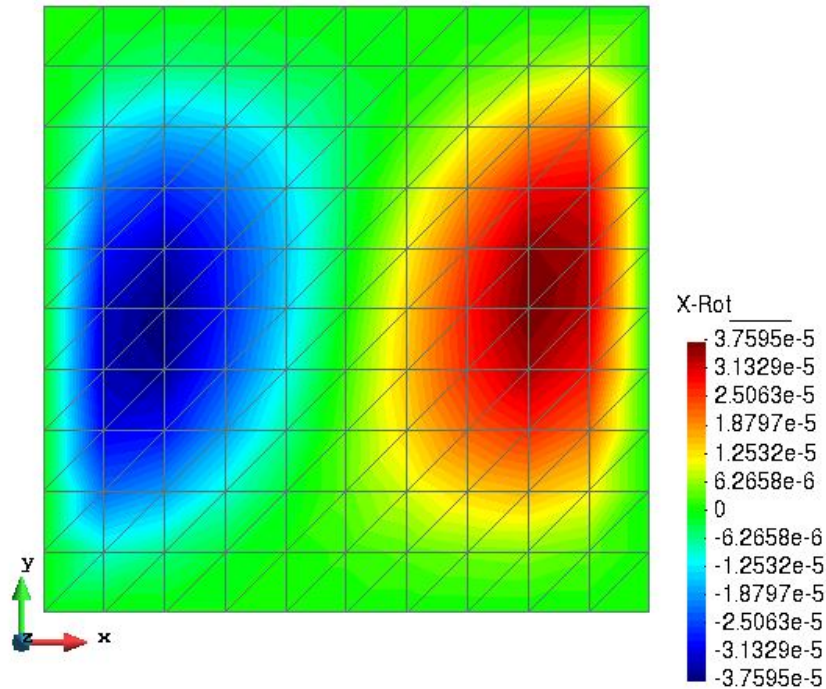


Figure 9: Rotation  $\theta_x$

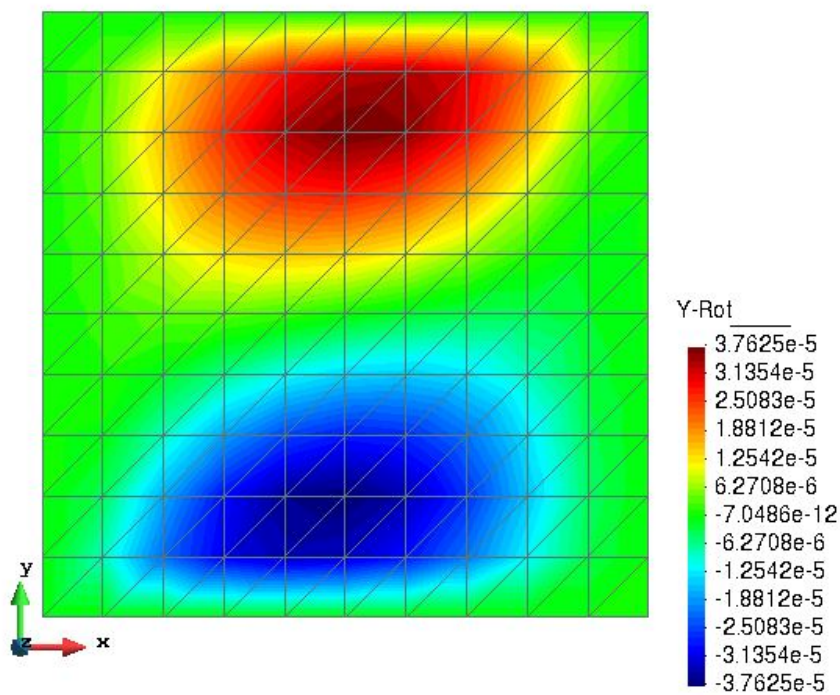


Figure 10: Rotation  $\theta_y$

Now, the membrane effects are shown in Figures 11-13 below:

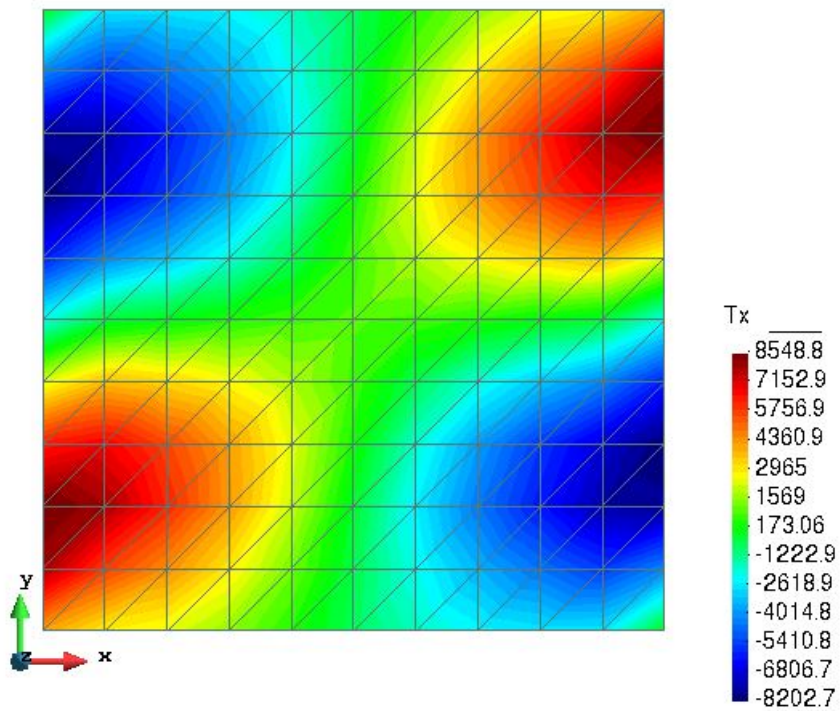


Figure 11: Membrane effects  $T_x$

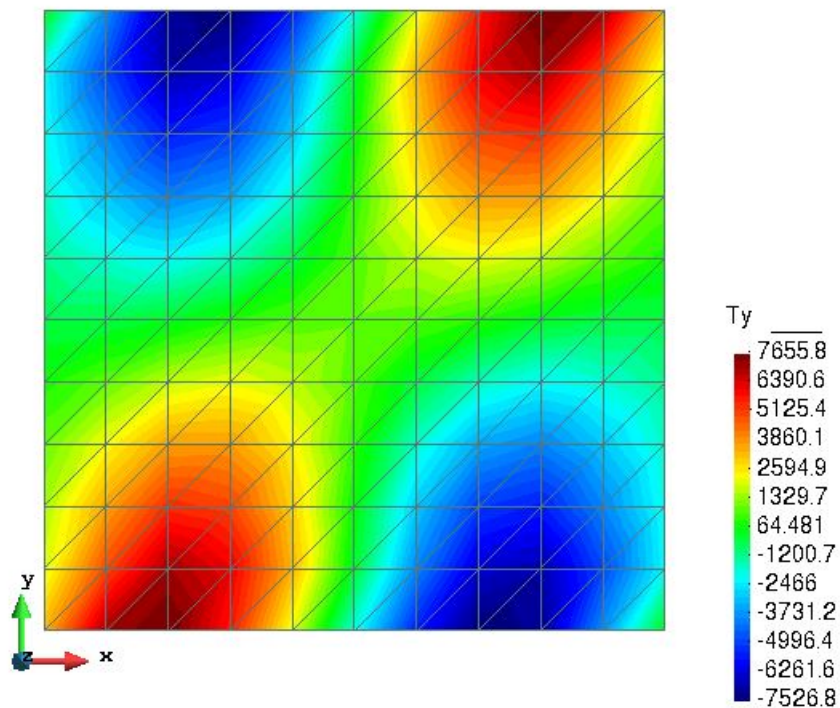
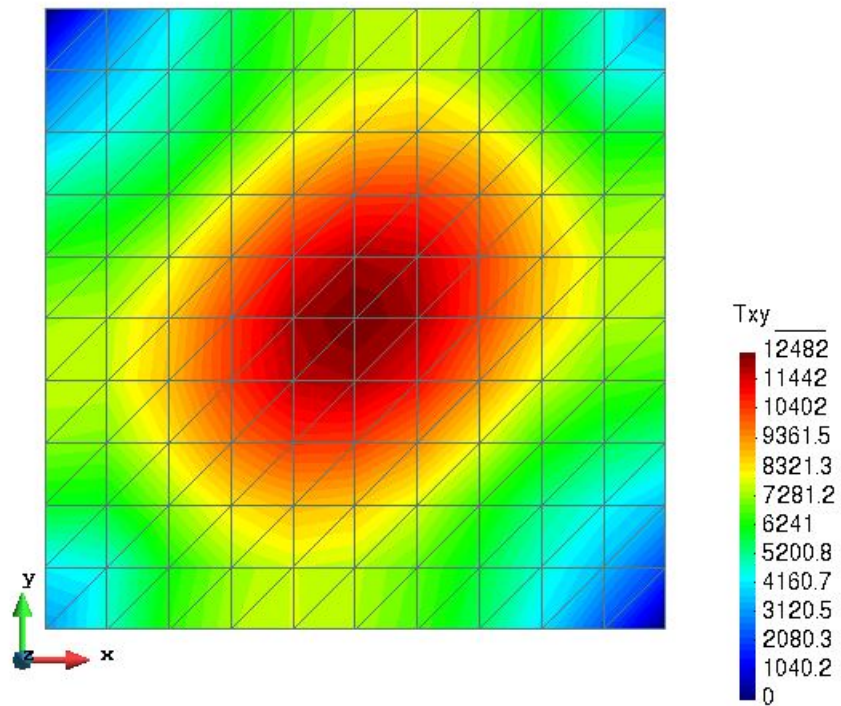


Figure 12: Membrane effects  $T_y$





**Figure 13:** Membrane effects  $T_{xy}$

The results for the membrane effects show the symmetry effects with maximum and minimum values seen in the upper and lower corners, respectively. Here  $T_x$  and  $T_y$  correspond to the compression or tension in the neutral axis. On the other hand,  $T_{xy}$  correspond to the forces that are parallel to the neutral axis like shear on the plane surface which is maximum in the middle and disappear on the boundaries.

Moments in the shell  $M_x$ ,  $M_y$  and  $M_{xy}$  are shown in Figures 14-16 below:

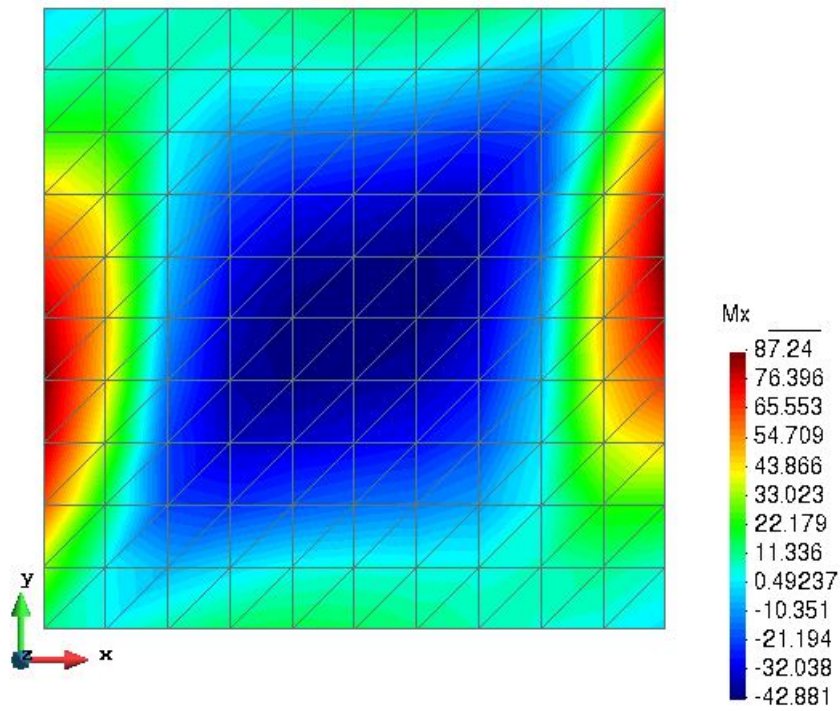


Figure 14: Moment  $M_x$

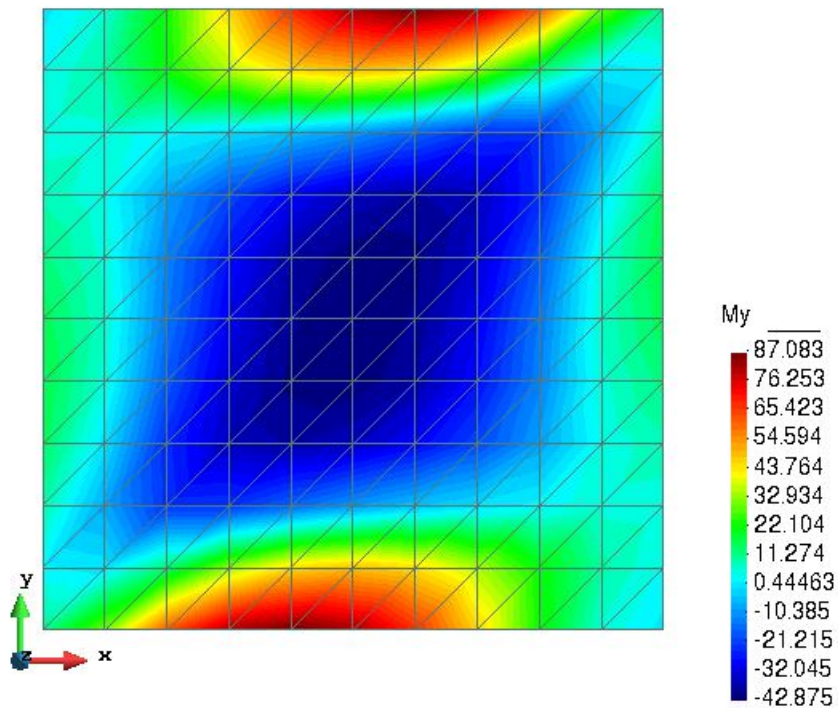


Figure 15: Moment  $M_y$

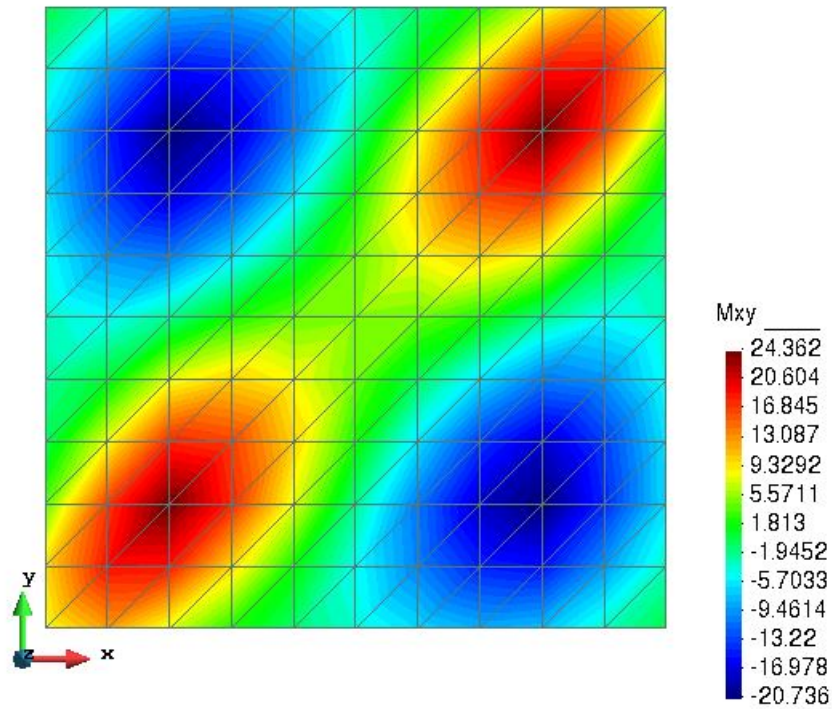


Figure 16: Moment  $M_{xy}$

The results for the moments show that in case of  $M_x$  and  $M_y$ , as expected, the maximum values are seen at the boundaries of the shell whereas the minimum values could be seen at the centre of the shell since the rotation effect vanishes. The symmetric effects can be seen in the result plot for  $M_{xy}$  which shows the combined effects of both moments.

Reaction forces in the shell are shown in the Figures 17-19 below:

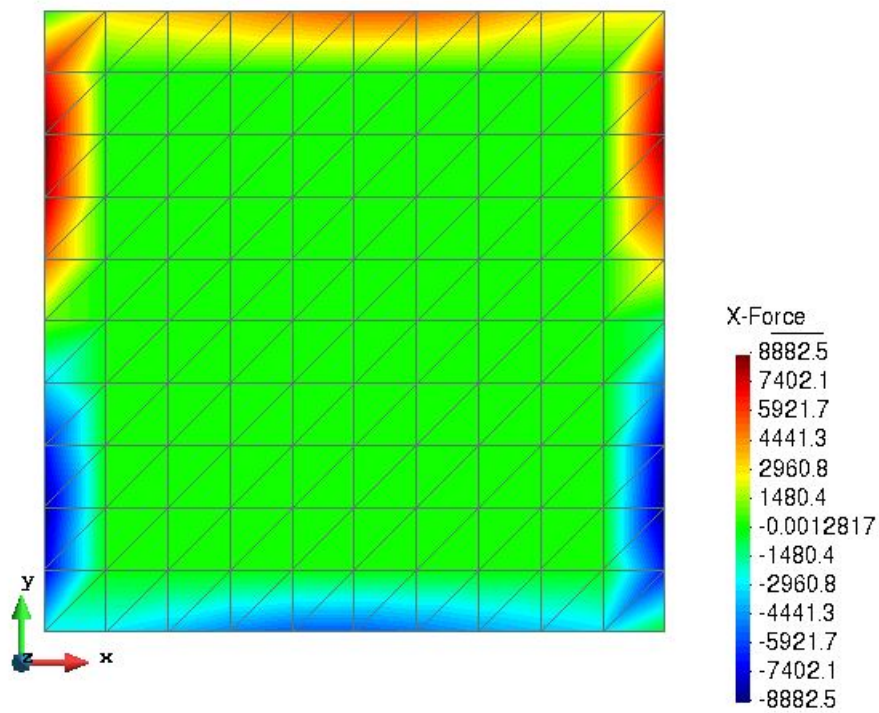


Figure 17: Reaction force in  $x$ -direction

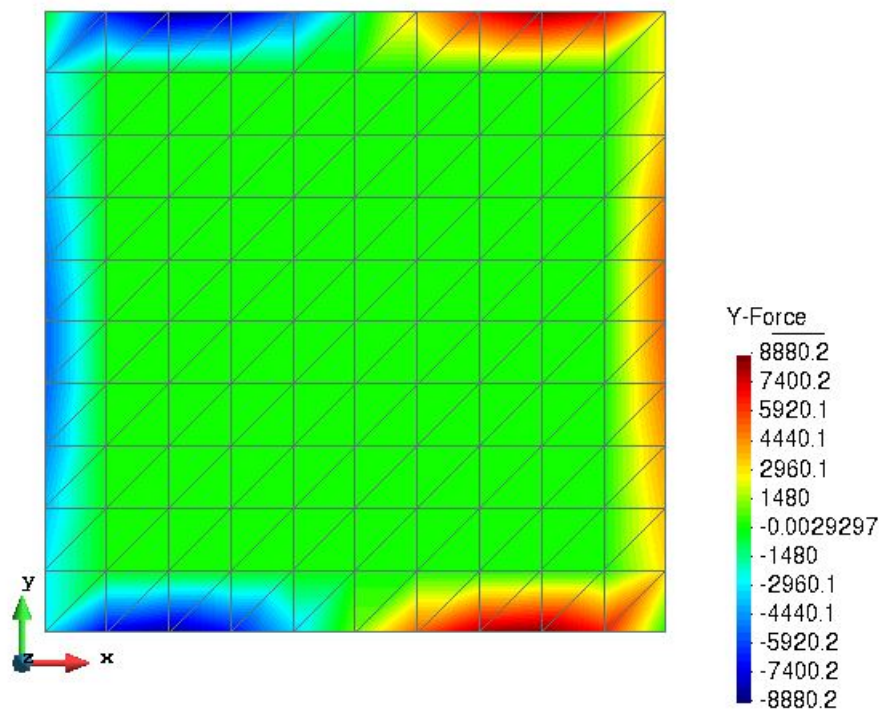


Figure 18: Reaction force in  $y$ -direction



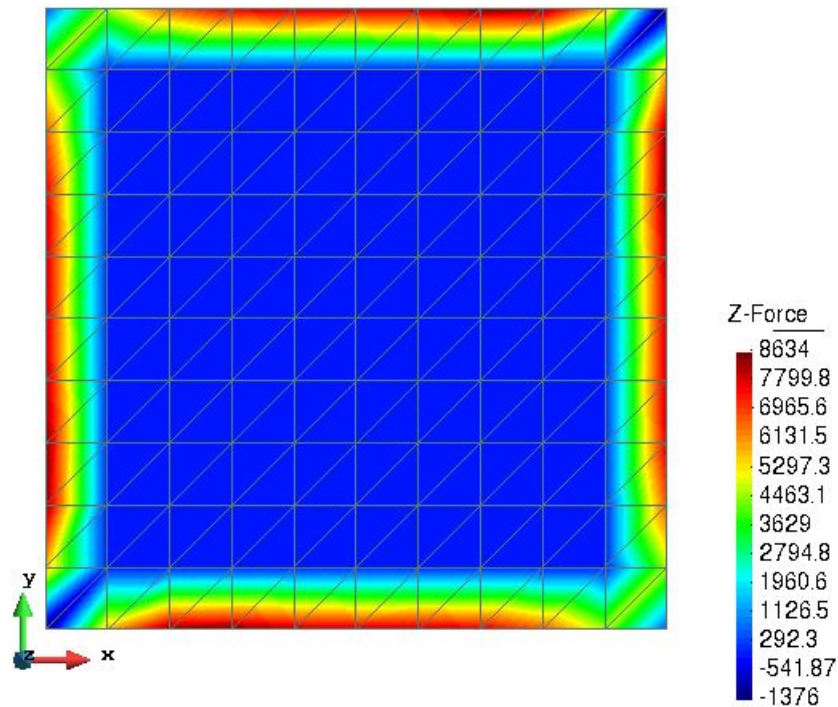


Figure 19: Reaction force in  $z$ -direction

The results for the reaction forces in  $x$ ,  $y$  and  $z$ -direction show the symmetric effects as expected. It is interesting to note that the results for  $x$  and  $y$  direction are just shows a rotated result with similar values. Since, the self-weight condition is applied in this problem, the  $z$ -direction reaction forces show important results with maximum reaction forces at the clamped end i.e. on all the boundaries and minimum at the centre of the shell.



Reaction moment are shown in the Figures 20 and 21 below:

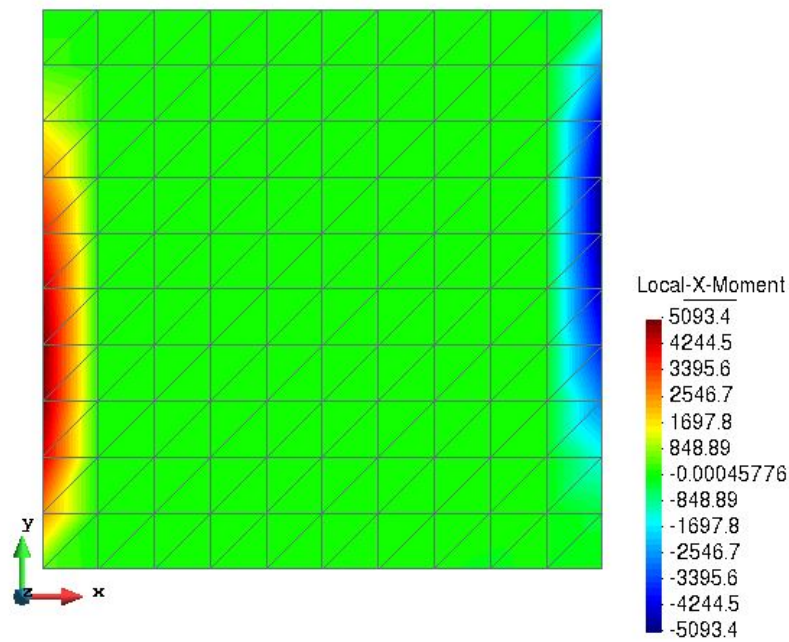


Figure 20: Reaction moment in  $x$ -direction

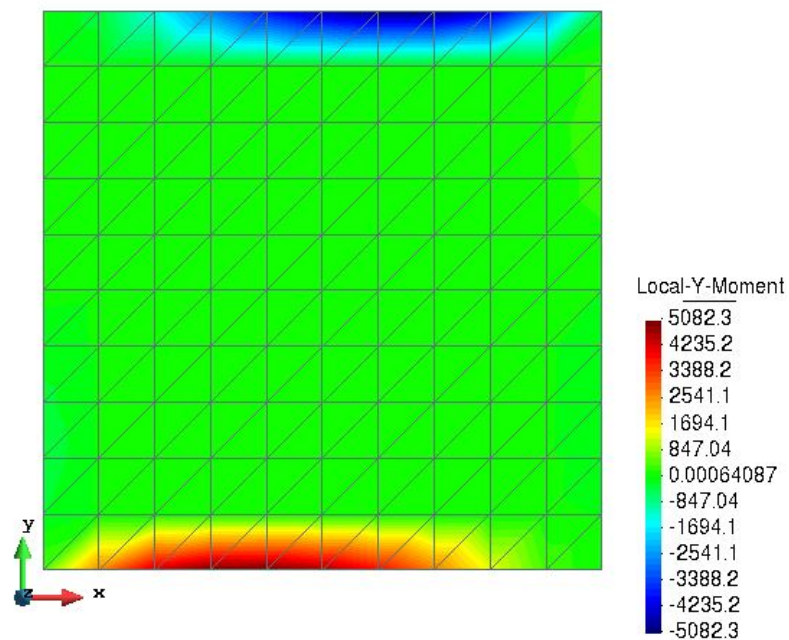


Figure 21: Reaction moment in  $y$ -direction

As expected, the symmetric effects are seen in the results for reaction moment in both directions with maximum on one side and minimum on the opposite side. The results in both directions are exactly same, but just rotated showing the symmetry of geometry and loading.

Finally, shear stresses results are shown in the Figures 22 and 23 below:

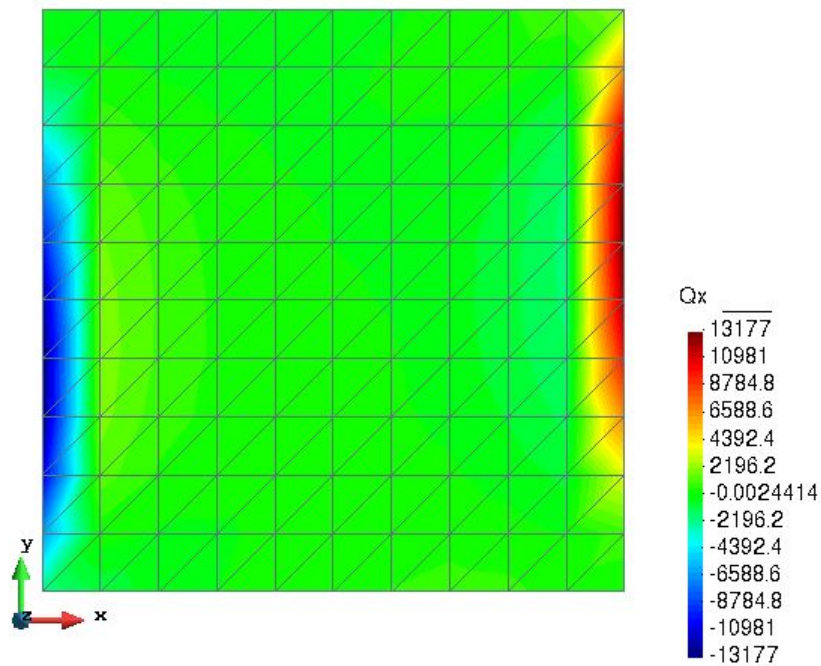


Figure 22: Shear stresses  $Q_x$

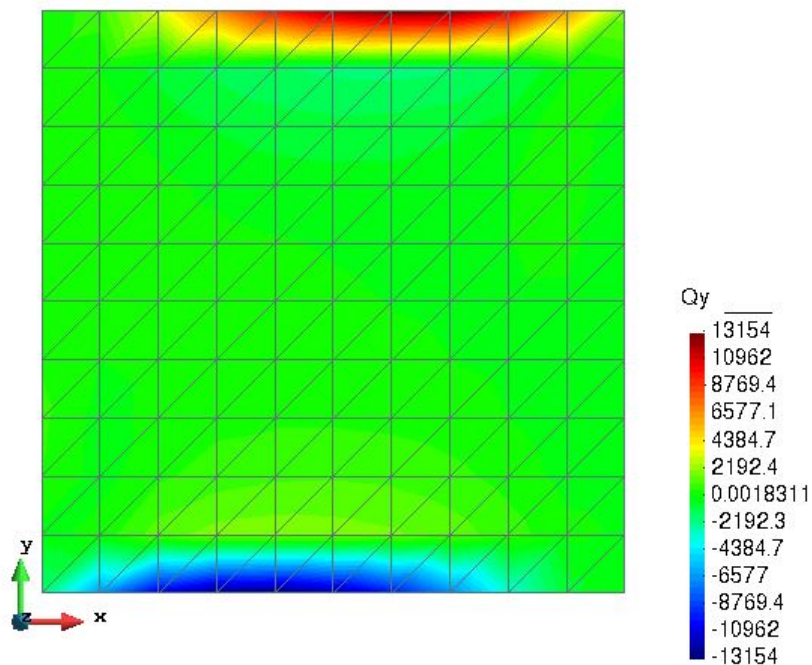


Figure 23: Shear stresses  $Q_y$

Again we see higher values of shear stress at the clamped boundaries and almost zero at the centre. As expected, the symmetry in the  $x$  and  $y$ -directions are clearly visible.