UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Computational Structural Mechanics and Dynamics

Master's Degree in Numerical Methods in Engineering

Assignment 8: Shells

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Contents

1 Analysis of a Hyperbolic Concrete Shell Under Self Weight

1.1 Problem Description

In this assignment, it is required to analyse the concrete hyperbolic shell under self-weight shown in Figure 1. The coordinates of the shell are specified in Figure 1. The material concrete has an Elastic Modulus $E = 3e10N/m^2$, $\nu = 0.2$, $\rho = 2.5e4kg/m^3$ and the thickness of the shell is $t = 0.1m$.

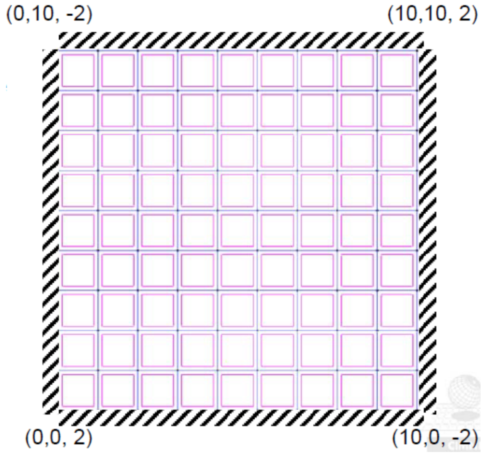


Figure 1: Geometry of the problem

It is used the interface $Matfem - Shells$ with GiD to create an input file to generate with the Matlab program ($Lamina_{RM}$) the results explained below for the shell. First, it is introduced the material properties and thickness. Moreover, it is introduced to all the sides of the shells a fixed constraint (clamped). It is considered the condition self-weight.

Secondly, it is created the mesh shown in Figure 2 that uses structured triangular Reissner-Mindlin elements with a size of $0.3m$. The mesh has 2.592 triangular and linear elements. It is considered this size due to the fact it gives a good convergence for the results and the triangular type of element because the Matlab program works with them.

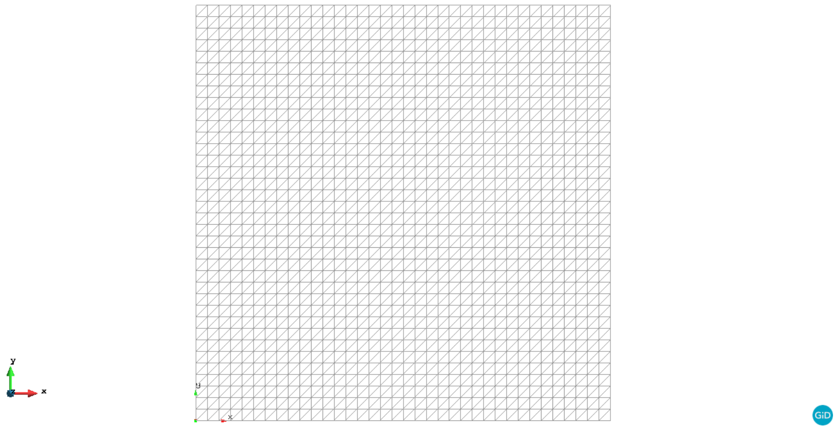


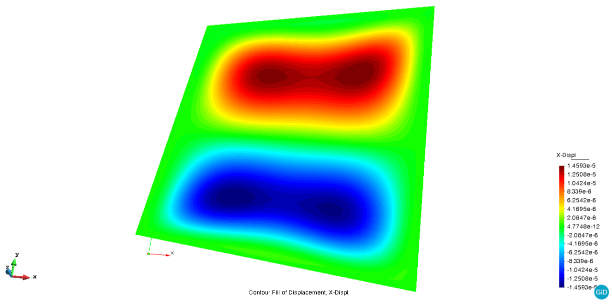
Figure 2: Mesh of the shell

Once the set-up is finished, it is created the input file for Matlab which gives the results. Finally, the program generates an input for the post-processing of GiD in order to see and study the results of the calculations for the stresses that the shell suffer.

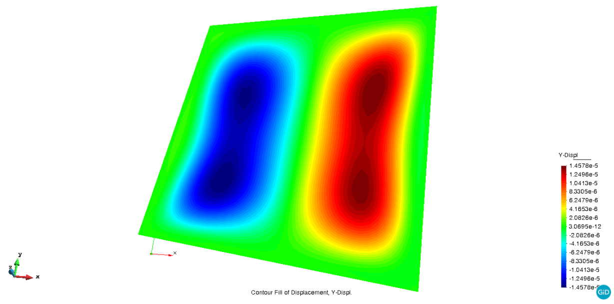
1.2 Displacements

The first variable to study the behaviour of the shell under its self-weight is the displacement produced. In Table 1 is shown the displacements in all directions and the deformation produced. It is chosen the Z-direction to show the deformation because the only force produced, the self-weight is acting on the shell in this direction. As all the sides are fixed, the highest displacement is produced in the centre of the shell as it was expected.

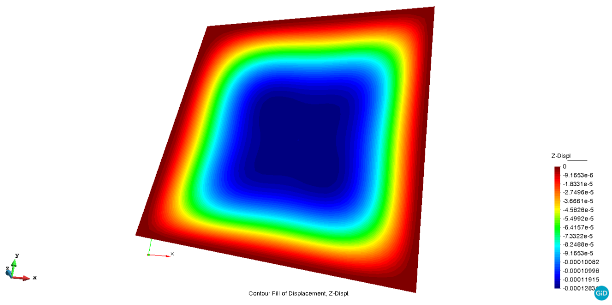
Furthermore, the X and Y displacements are symmetric in absolute value respect their axis (in one side, they are positive and in the other, negative).



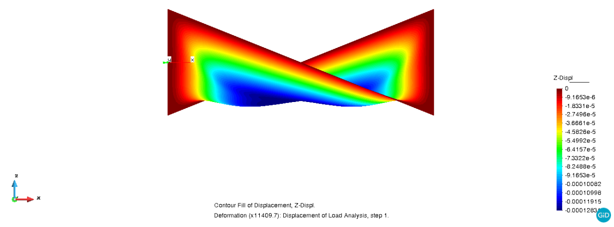
(a) Displacement in X-direction



(b) Displacement in Y-direction



(c) Displacement in Z-direction

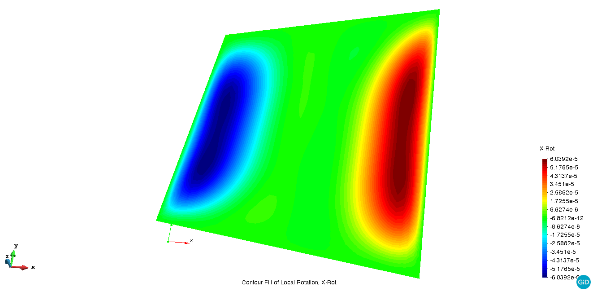


(d) Deformation produced

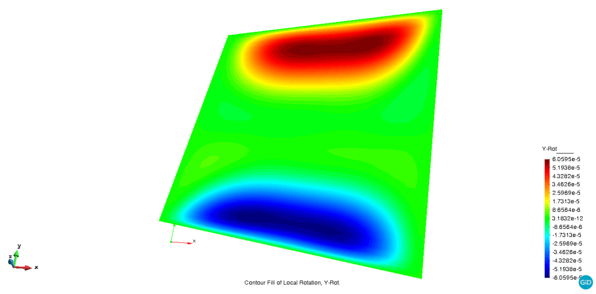
Table 1: Displacement results for the shell.

1.3 Rotations

In Figure 3, it is shown the distribution of the rotation around the axes X and Y. As it was produced in the displacement field, due to the self-weight and the clamped conditions, both plots show symmetric distribution respect to the perpendicular axis of the study. This means that rotations around the axis Y are symmetric respect to the X and vice versa. The highest values are situated close to the edges.



(a) Rotations around axis X



(b) Rotations around axis Y

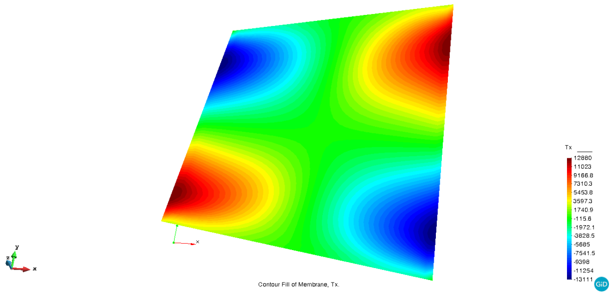
Figure 3: Rotation results for the shell.

1.4 Membrane Stresses

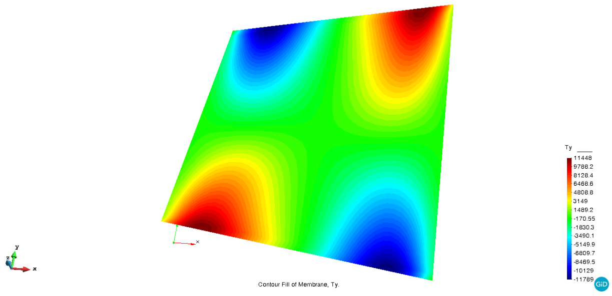
Next, it is presented the plots in Table 2 that shown the membrane stresses acting on the hyperbolic shell.

Once again, it is possible to notice the symmetric distribution behaviour of the axial forces across the shell. The maximum values for Tx are bigger than Ty. It is noticed that the corners which have the highest values for tensile stresses are the one which the coordinate $z = 0$. In the same manner, when the coordinate is $z < 0$ it is produced the highest negative compressive stress values for Tx and Ty. As for the Txy stresses, it is noticed that the highest value is produced in the centre of the shell because it is where the highest Z-displacement is produced.

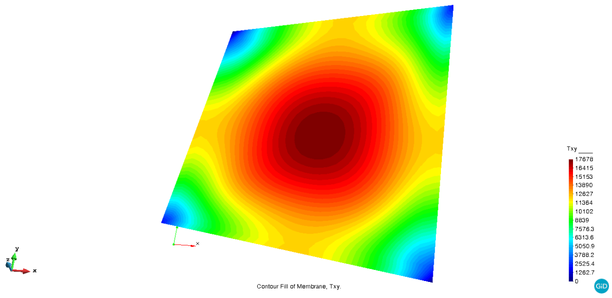
These results agree with what was expected from a concrete shell supported just under its self-weight. The effect of the weight pulls on the elevated zones (z-coordinate) and pushes into the lower zones.



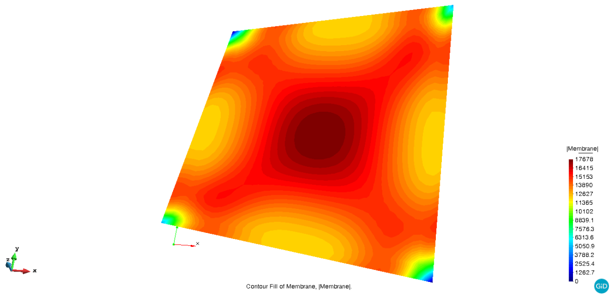
(a) Tx



(b) Ty



(c) Txy



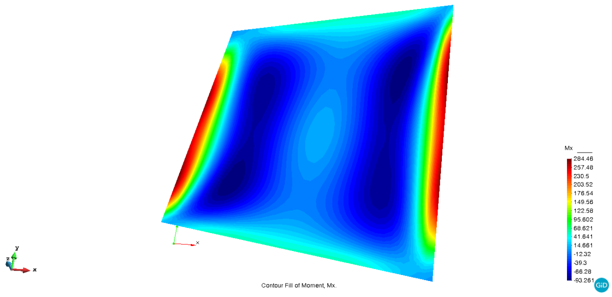
(d) Norm of the membrane force

Table 2: Membrane stress results for the shell.

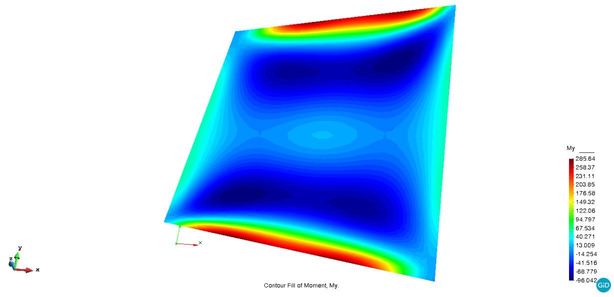
1.5 Bending Moments

In Table 3, it is shown the bending moment produced in the shell. In the same way as the membrane forces, the bending moments have the same symmetrical behaviour. In this case, the highest values are situated on the sides of the shell because the structure is fixed in both directions.

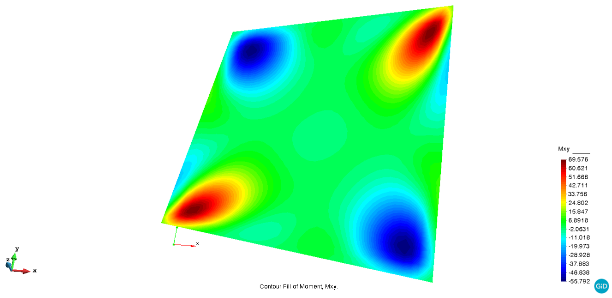
As for the torsional moment in the X-Y direction, there are two directions of symmetry corresponding to the two diagonals of the shells. The maximum values are in the corners due to the gravity which creates the torsional effect in this hyperboloid shape of the shell.



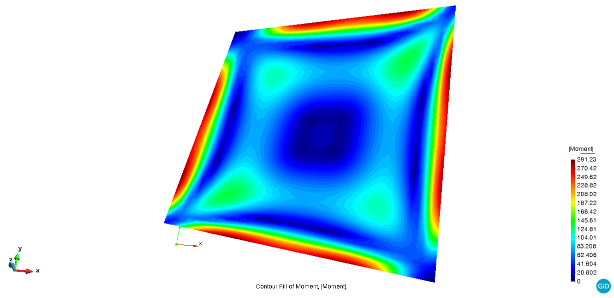
(a) Moment in X-direction



(b) Moment in Y-direction



(c) Moment in X-Y direction

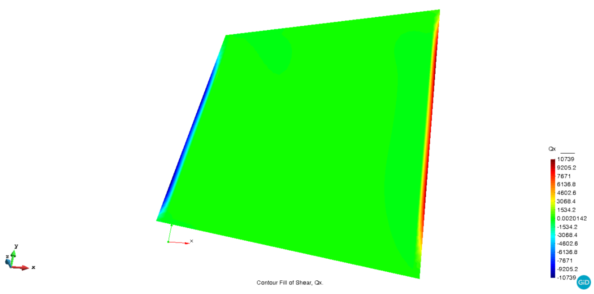


(d) Norm of the bending moment

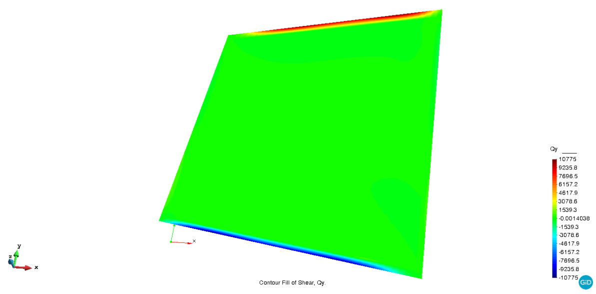
Table 3: Bending moment results for the shell.

1.6 Shear Stresses

Finally, it is shown in Figure 4 the shear stresses produced. Due to the fact of the fixed constraints and the hyperboloid shape of the shell, the highest values are obtained in the normal direction of the shell side for each direction studied. Moreover, it is produced a symmetric behaviour of the stresses in absolute value. The shear forces remain constant along the shell until they reach the extremes, that vary sharply.



(a) Shear stress in X-direction



(b) Shear stress in Y-direction

Figure 4: Shear stress results for the shell.