UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Escola Tècnica Superior d'Enginyers de Camins, Canals i Ports de Barcelona

MSc Computational Mechanics

Computational Structural Mechanics and dynamics

Shell with plate elements

Author:
Shushu Qin

Supervisor:
Dr.Francisco Zárate

1 Introduction

A hyperbolic paraboloid (sometimes referred to as 'hp') is a doubly-curved surface that resembles the shape of a saddle, that is, it has a convex form along one axis, and a concave form on along the other. It is also a doubly-ruled surface, that is, every point on its surface lies on two straight lines across the surface. Horizontal sections taken through the surface are hyperbolic in format and vertical sections are parabolic.
To solve the given 'hp' shell, the Reissner-Mindlin shell theory for thin/thick shells has been considered.A shell can be regarded as the extension of a plate to a non-planar surface. The non-coplanarity introduces axial (membrane) forces in addition to bending and shear forces, thus providing a higher overall structural strength. A 'shell element' combines a bending and shear behaviour and an 'in-plane' (membrane) one. The shell surface is discretized into 3-node triangle DKT elements combining the 3-node plane stress triangle element. The results are compared with the those of a flat shell.

2 Preprocess

The geometry generated by Gid is shown in Figure 1.

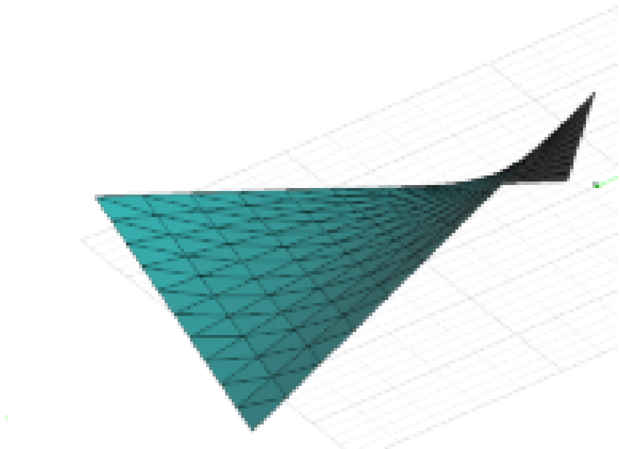


Figure 1: Geometry

Self-weight is considered. The material properties are

$$\begin{aligned} E &= 3e + 10\texttt{Pa} \\ \nu &= 0.2 \\ \rho g &= 2.5e + 4\texttt{N/m}^3 \\ \texttt{thickness} &= 0.1m; \end{aligned} \tag{1}$$

The all clamped boundary conditions are applied.

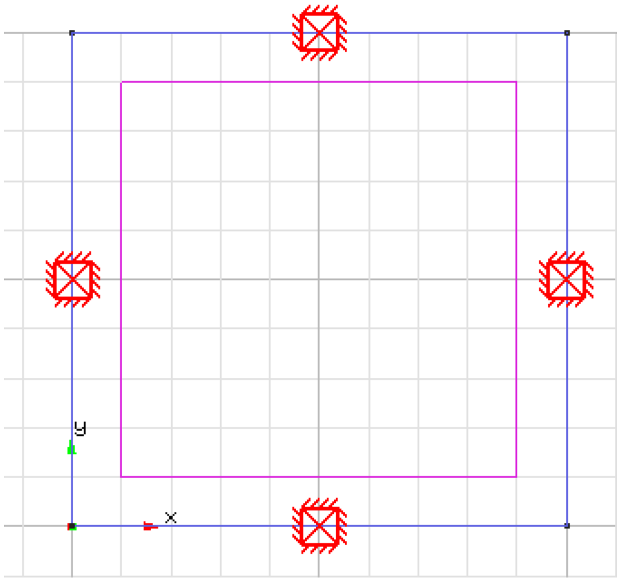


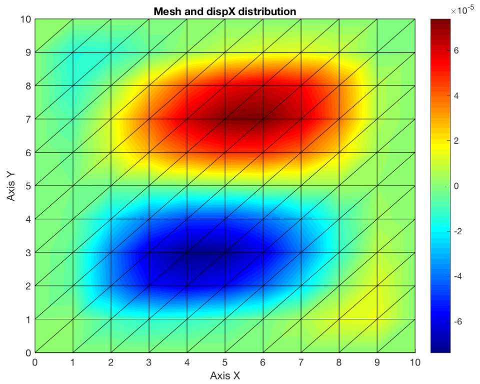
Figure 2: Boundary conditions

3 Results

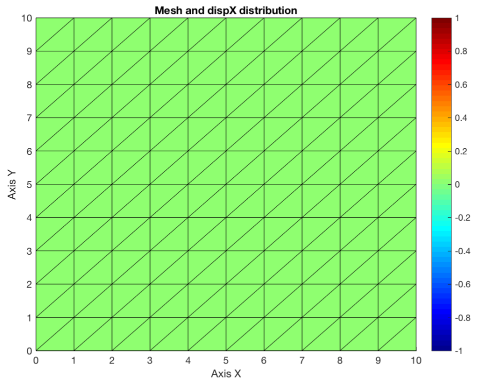
The exported .m file is utilized as the input file for the matlab code to obtain the various solutions for the given shell. The solutions are depicted as follows.

3.1 Displacements and rotation

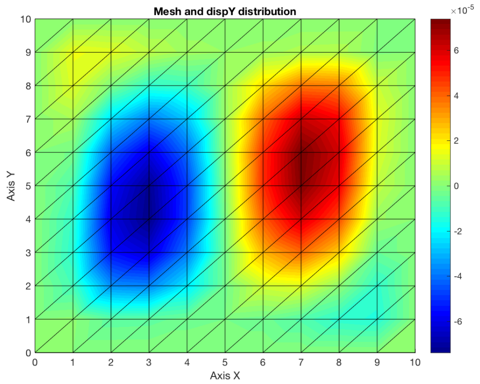
As we can see from Figure 3, the displacement in Z direction of a flat shell is more than twice of the HP shell. Similarly, the rotation of the flat shell is far larger than that of the HP one.The HP shell shows greater rigidness in the deformation.



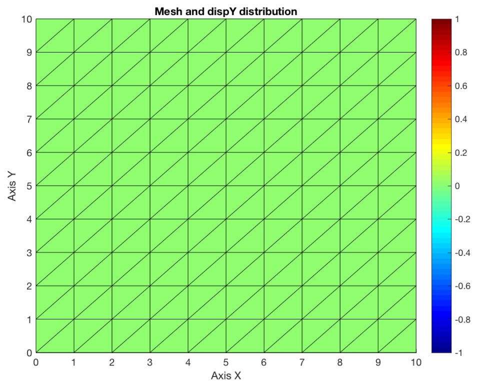
(a) HP dispX



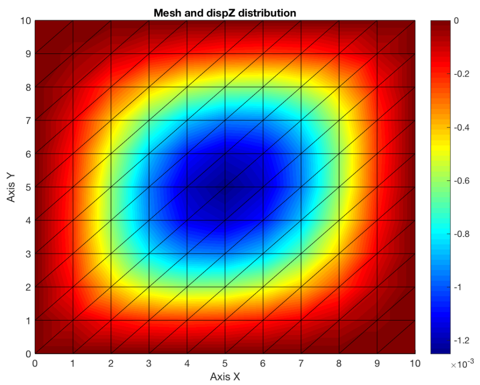
(b) flat dispX



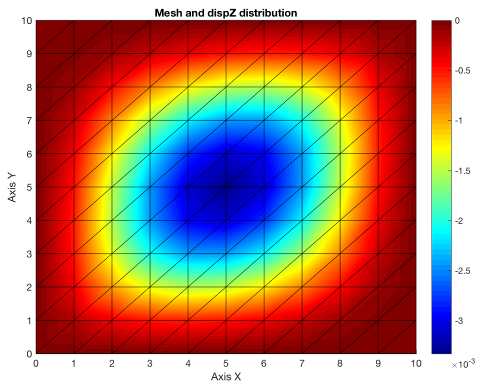
(c) HP dispY



(d) flat dispY

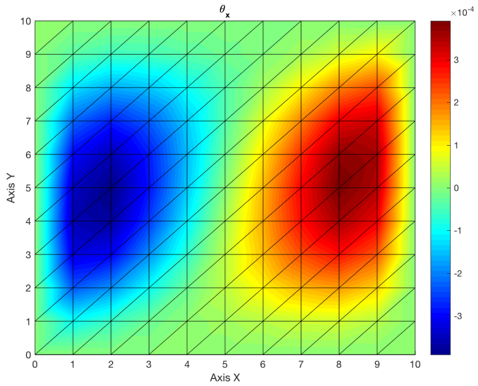


(e) HP dispY

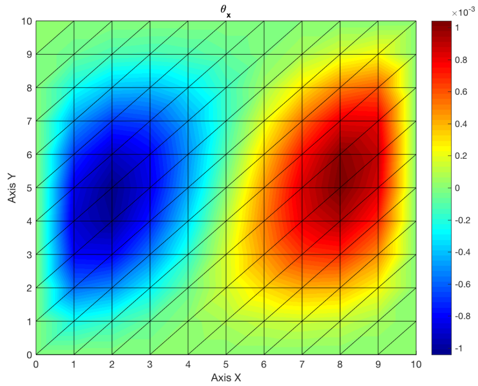


(f) flat dispZ

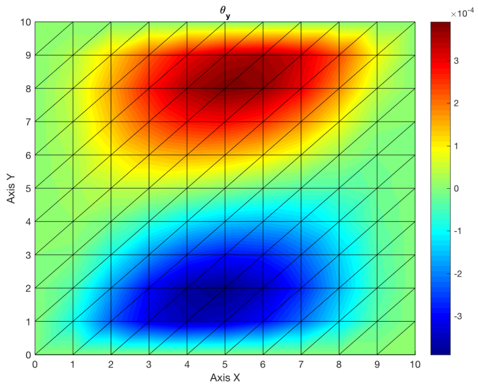
Figure 3: Displacement fields



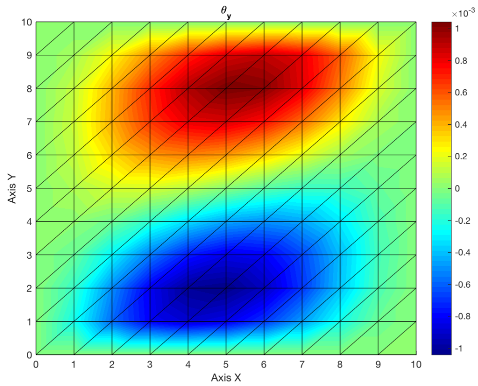
(a) HP Rotation X



(b) flat Rotation X



(c) HP Rotation Y

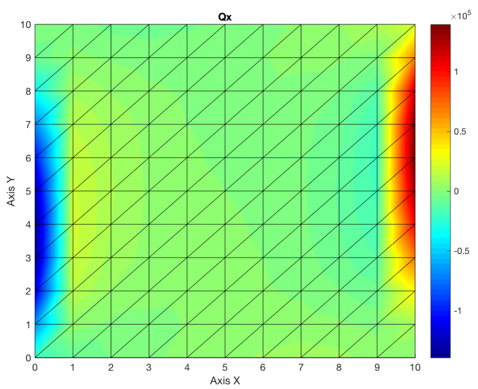


(d) flat Rotation Y

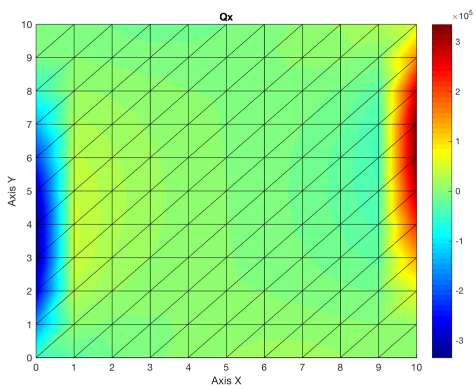
Figure 4: Rotation fields

3.2 Shear and Moment

The shear stress force and the moment in the flat shell is higher than that in the HP shell.

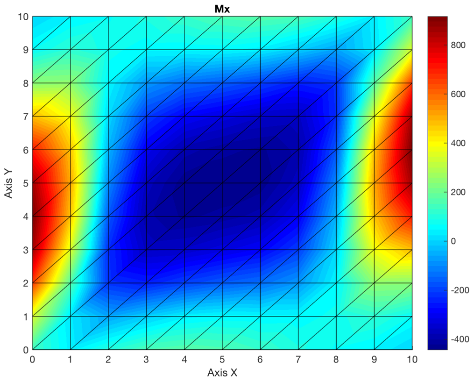


(a) HP shear x

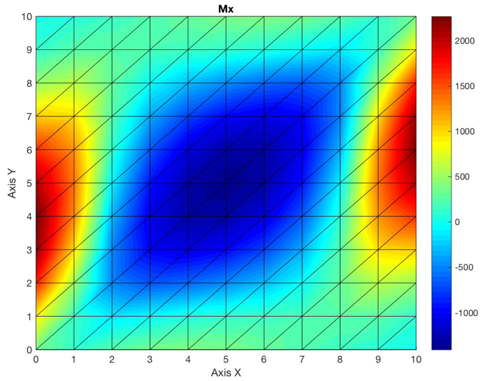


(b) flat shear x

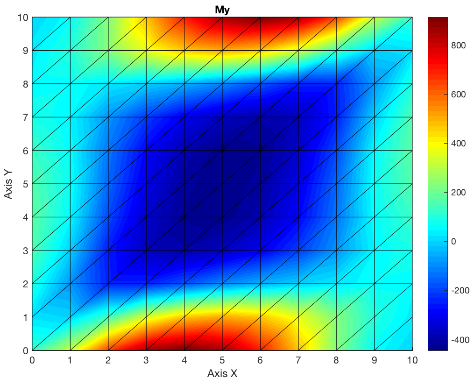
Figure 5: Q_x



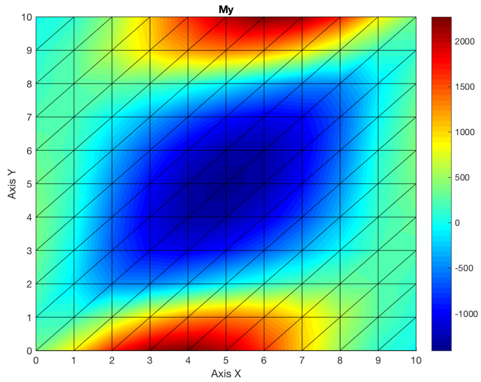
(a) HP M_x



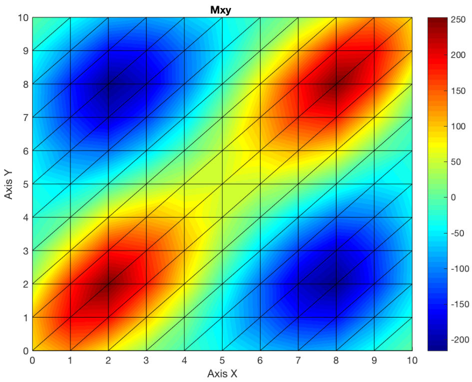
(b) flat M_x



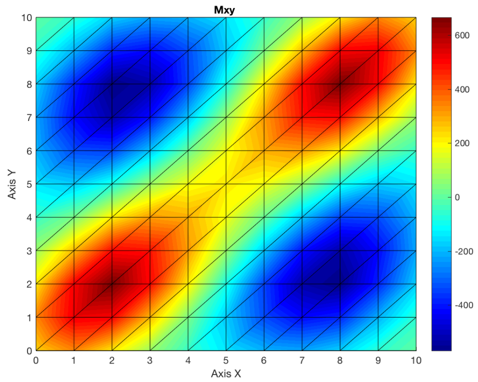
(c) HP M_y



(d) flat M_y



(e) HP M_{xy}

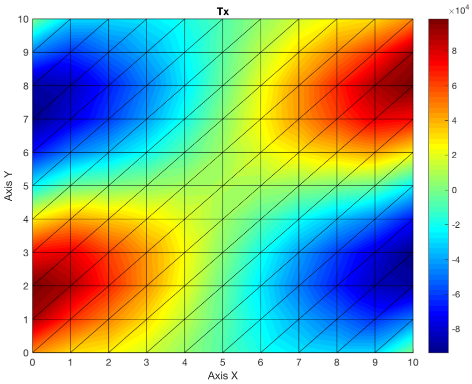


(f) flat M_{xy}

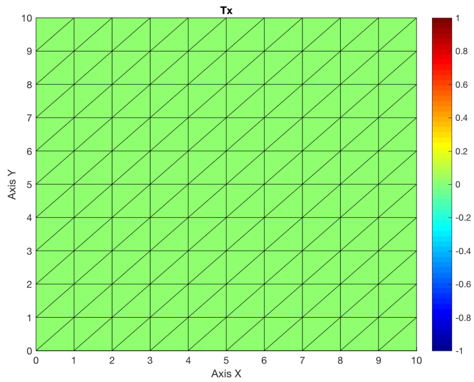
Figure 6: Moment fields

3.3 Membrane stresses

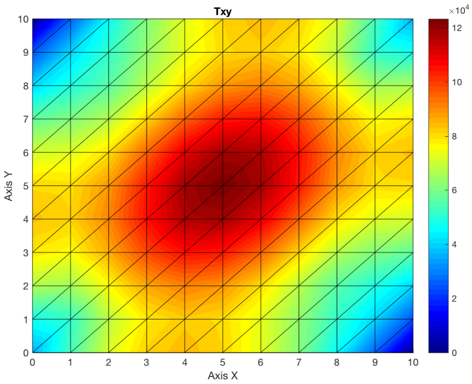
In HP shell, compressive stresses and tensile strains are formed along the diagonal lines. In the flat shell, the surface is planar, so there is no membrane stress inside.



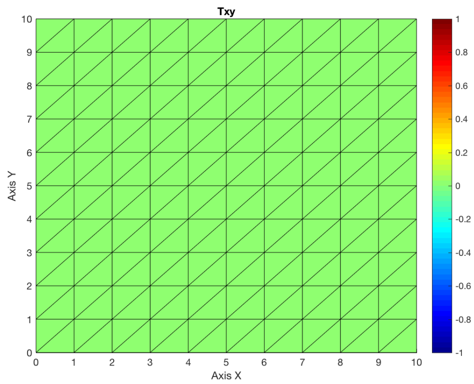
(a) HP T_x



(b) flat T_x



(c) T_{xy}



(d) flat T_{xy}

Figure 7: Membrane stresses

4 Conclusion

In conclusion, rather than derive their strength from mass, like many conventional roofs, HP shell roofs gain strength through their shape. The curvature of the shape reduces its tendency to buckle in compression (as a flat plane would) and means that they can achieve exceptional stiffness.