Computational Structural Mechanics and Dynamics

Assignment: Shells

Clamped hyperbolic shell

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SUMMARY

Problem description

The concrete hyperbolic shell presented on the slides is solved by means of triangular RM elements: The geometry and mesh are created with GID and Mat-FEM, the calculation of the results is carried out with the code of Mat-FEM "Shell_T_RM_v1.1" implemented in Matlab. And the post-processing and posterior analysis is done with GID.

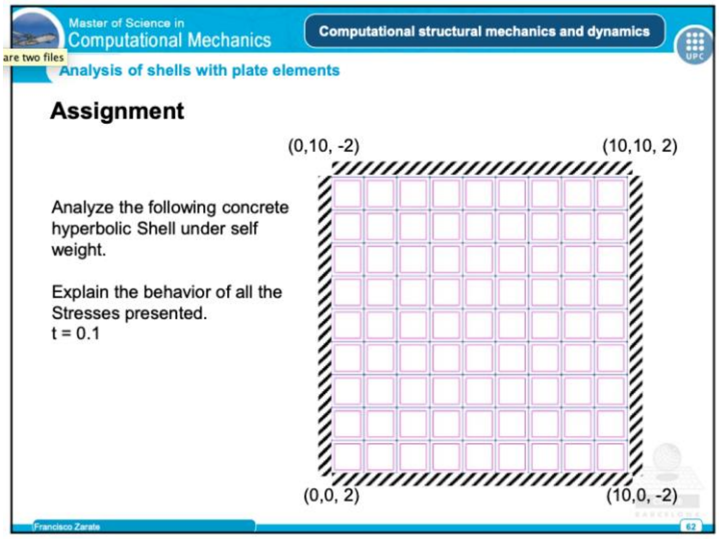

Figure 1: Problem description

The mesh used to represent the geometry is a uniform one with 10 triangular elements per side. The total number of nodes is 121 and the number of elements is 200.

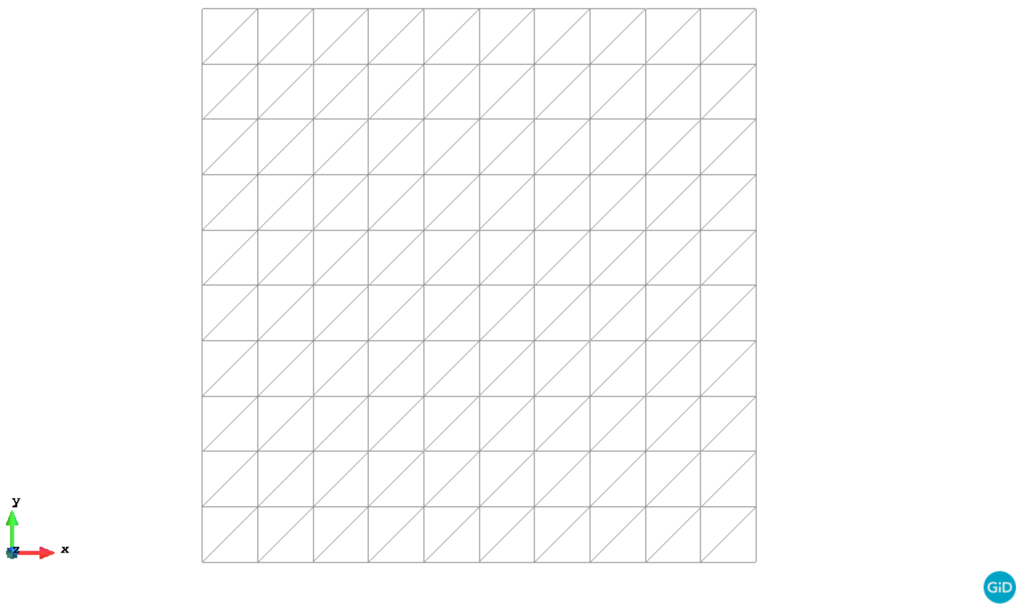

Figure 2: Mesh of the problem

All the boundaries are fully constrained (displacements and local rotations) in order to represent a clamped shell.

The material parameters of concrete selected to solve the elastic problem are presented in the following table.

Table 1: Material properties

Elasticity modulus [GPa]	30
Poisson ratio	0.2
Density [N/m3]	25000
Thickness [m]	0.1

Results

All the results presented below are plotted by its x-y plane view.

Displacements

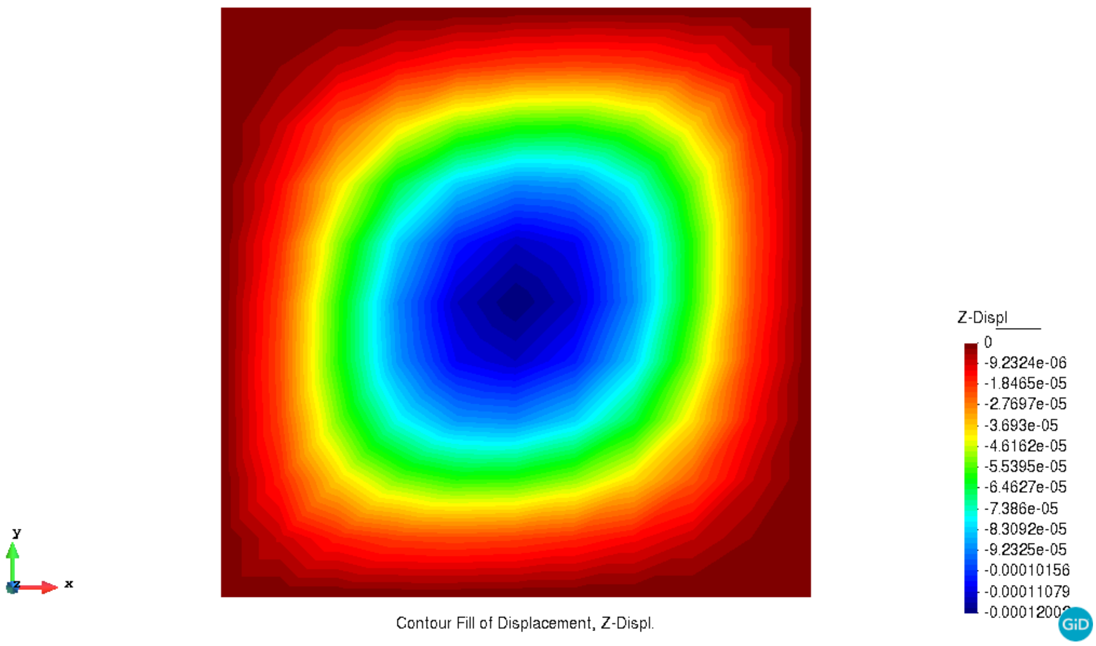

Figure 3: Displacements in z-direction

It is worth noting that the maximum displacement occurs at the centre of the shell. As it was expected, with its own weight as the only load of the structure, the area which is farther of the constrained boundaries is the most deformed. Since the maximum absolute value of the displacement is less than 1 mm, it can be considered small.

Membrane tensions

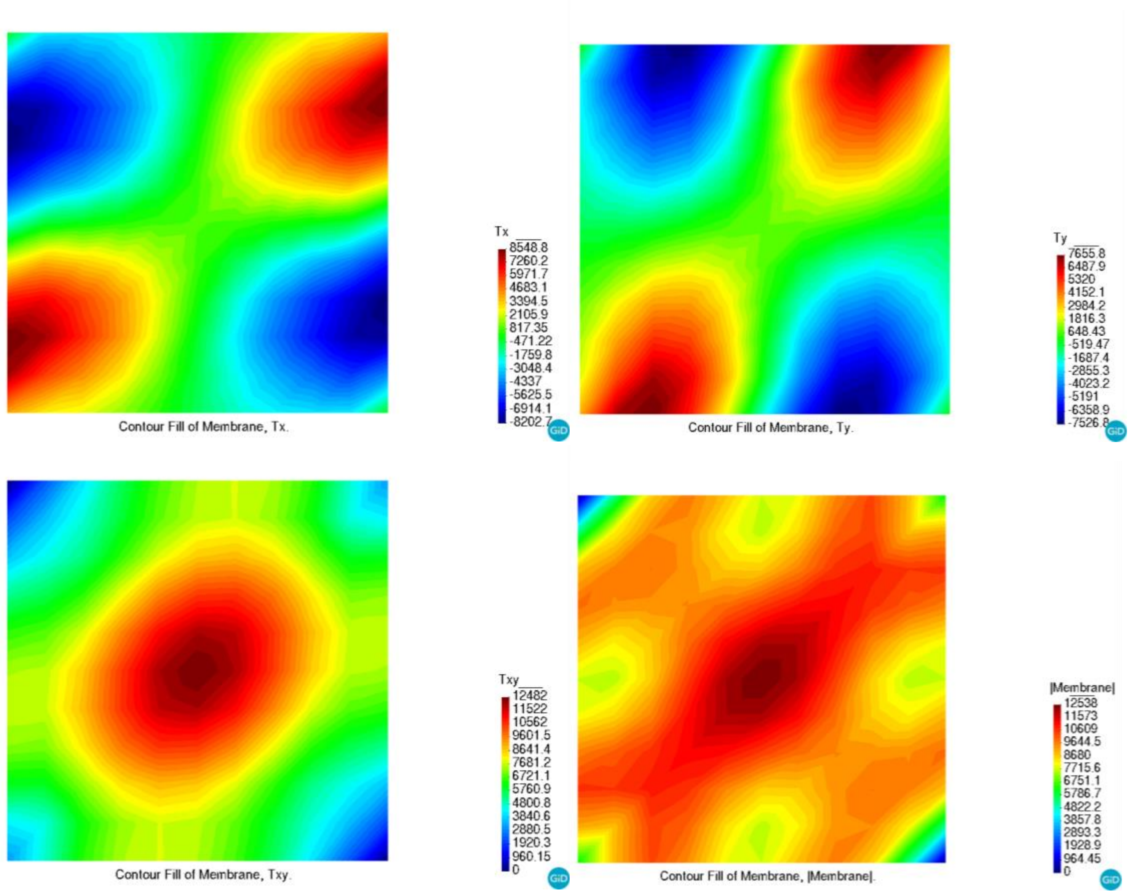

Figure 4: Membrane (in-plane) forces

This membrane values indicate the forces appeared along the x-y plane (mid-plane of the structure). As can be seen, the hyperbolic geometry ease the emergence of larger values of in-plane internal forces. And this is simply because a component of the self-weight is loading in the direction of the mid-plane in some areas of the structure. The x and y components show us that the higher areas are under tension (red), and the lower ones are under compression (blue). Furthermore, the norm of the membrane forces indicates that the most loaded area combining this "in-plane loads" is the saddle point situated at the centre.

Moments

Regarding the resulting moments along the structure, as can be seen, the x and y moments reach their respective peak near the boundaries and the middle area presents large compressive moments, which are appropriate for the concrete porperties. Meanwhile, the M_{xy} moment show larger values around the steeper areas and a symmetric distribution which coincides with the symmetry of the structure. It is worth noting that the moment distribution is similar to the one presented in a clamped flat square plate of similar characteristics, although the hyperbolic geometry achieves lower absolute values because the gravity does not generate moment as easily as in the flat case.

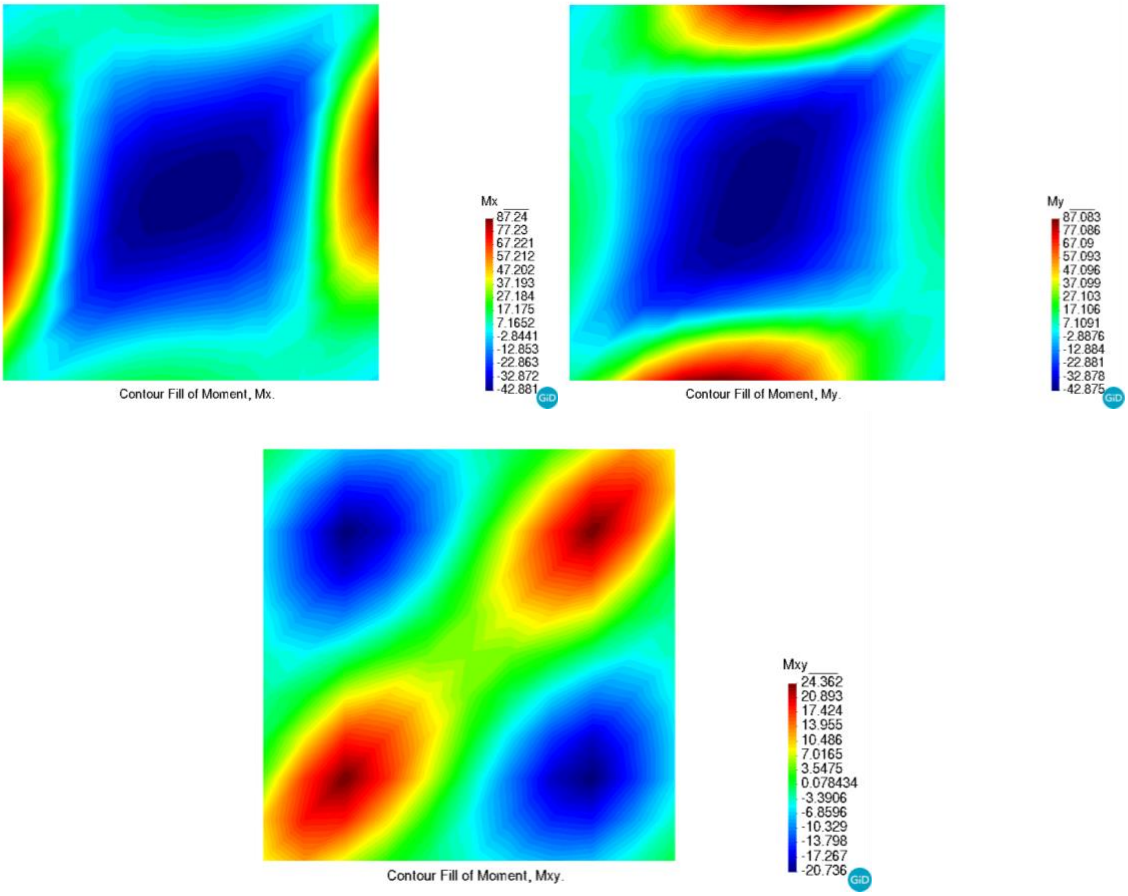

Figure 5: Moments in x and y directions

Shear

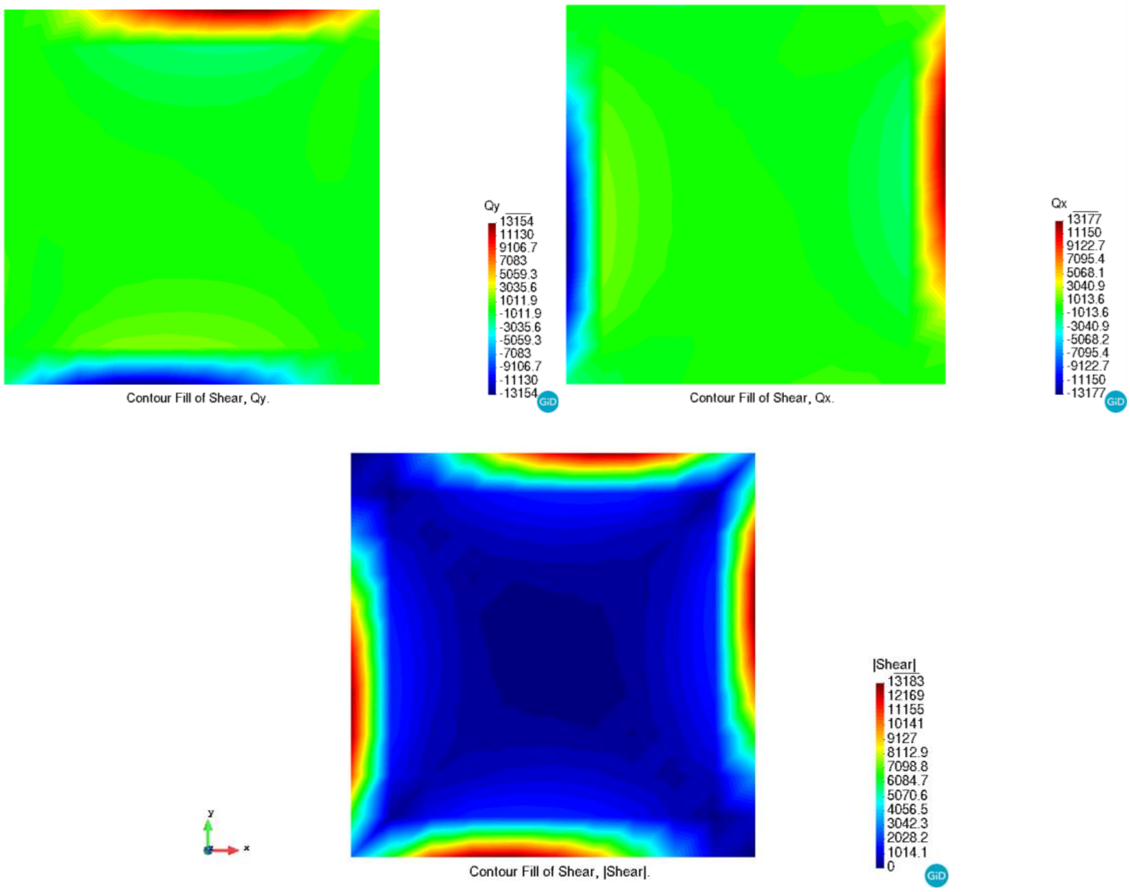

Figure 6: Shear in x and y directions

As can be seen, the shear forces are larger near the boundaries. The results are distributed symmetrically but with opposite signs. As previously mentioned, the hyperbolic shape helps to decrease also the shear forces thanks to the component of the gravity which is loading partially in-plane along the structure.

Conclusions

To sum up, the analysis of the results shows that the hyperbolic shape is appropriate for roofs and this kind of structures which are under its own weight because distributes the gravity load better than for instance a flat plate. Therefore, it would mean an important reduction of the material needed to build this type of structures. However, from an engineering point of view, further analysis should be done to assess whether it is a better solution, taking into account manufacturing costs, which could be significant due to the special geometry, and could become this kind of structure unprofitable in some cases.