UNIVERSITAT POLITÈCNICA DE CATALUNYA

MASTER IN COMPUTATION MECHANICS AND NUMERICAL METHODS IN ENGINEERING

COMPUTATIONAL STRUCTURAL MECHANICS AND DYNAMICS

ASSIGNMENT 8

by

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1- Introduction

The goal of the assignment is to analyze a hyperbolic shell structure made of concrete. The shell theory chosen was the Reissner-Mindlin flat shell theory. The structure is fixed on its contour and is under self-weight.

2 – Structural Analysis

The following structure was considered with t = 0.1 [1]:

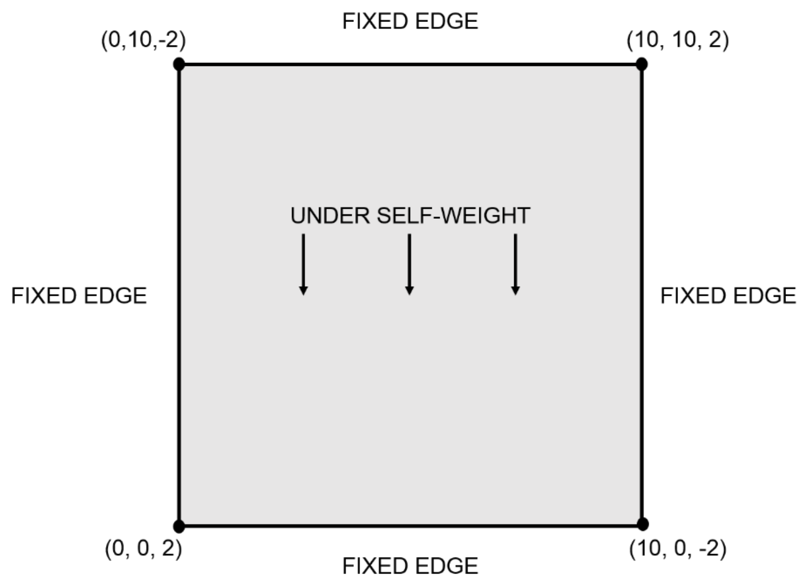

Figure 1. Hyperbolic shell structure under analysis.

and the following material properties were considered:

Table 1. Material properties considered.

Young Modulus [Pa]	Poisson	Density [kg/m³]
3e10	0.2	25000

Before analyzing displacements and stresses, a mesh convergence study was carried out in order to provided representative results with less computational time. Different sizes of element h were considered. Figure 2 depicts the mesh convergence and computational time versus number of nodes. The maximum normal displacement was chosen as the convergence parameter.

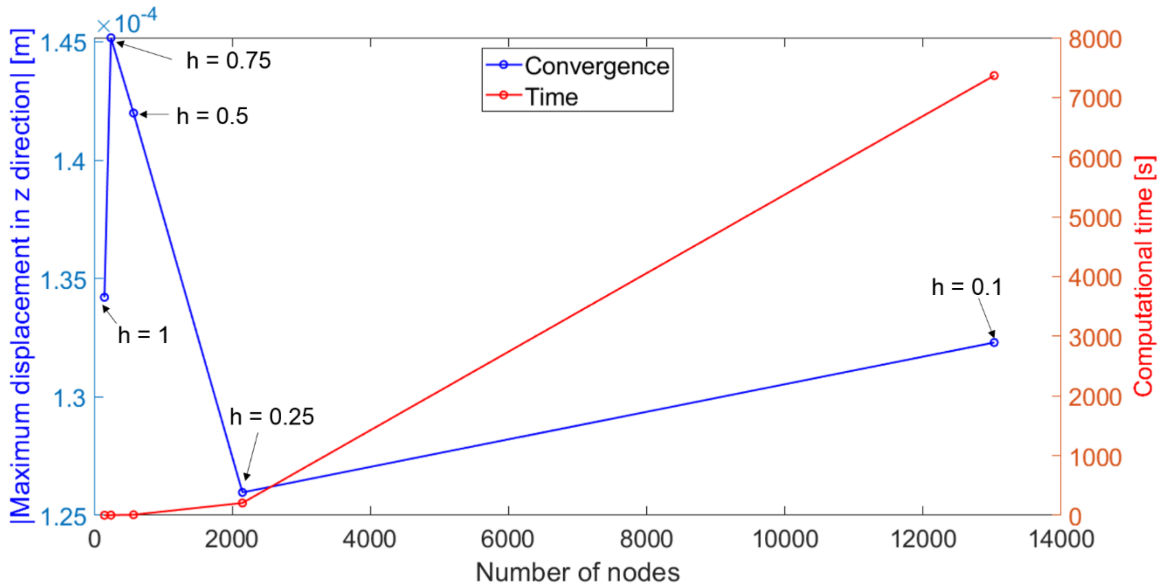

Figure 2. Mesh convergence and computational time versus number of nodes.

According to Figure 2, the computational time increases greatly when the mesh size h = 0.1 is applied for the discretization of the domain. Therefore, the mesh size chosen for the analysis the structure was h = 0.25. With such mesh size, the corresponding |maximum displacement in z direction| is more representative when compared to larger mesh sizes. Also, the computational time for h=0.25 does not increase significantly when compared to the computational time of larger mesh sizes. Therefore, the mesh size h=0.25 is suitable for the structural analysis of the hyperbolic shell structure depicted in Figure 1.

First, the displacement fields in the global coordinate system were analyzed. Figure 3 depicts the displacement fields in x, y and z directions.

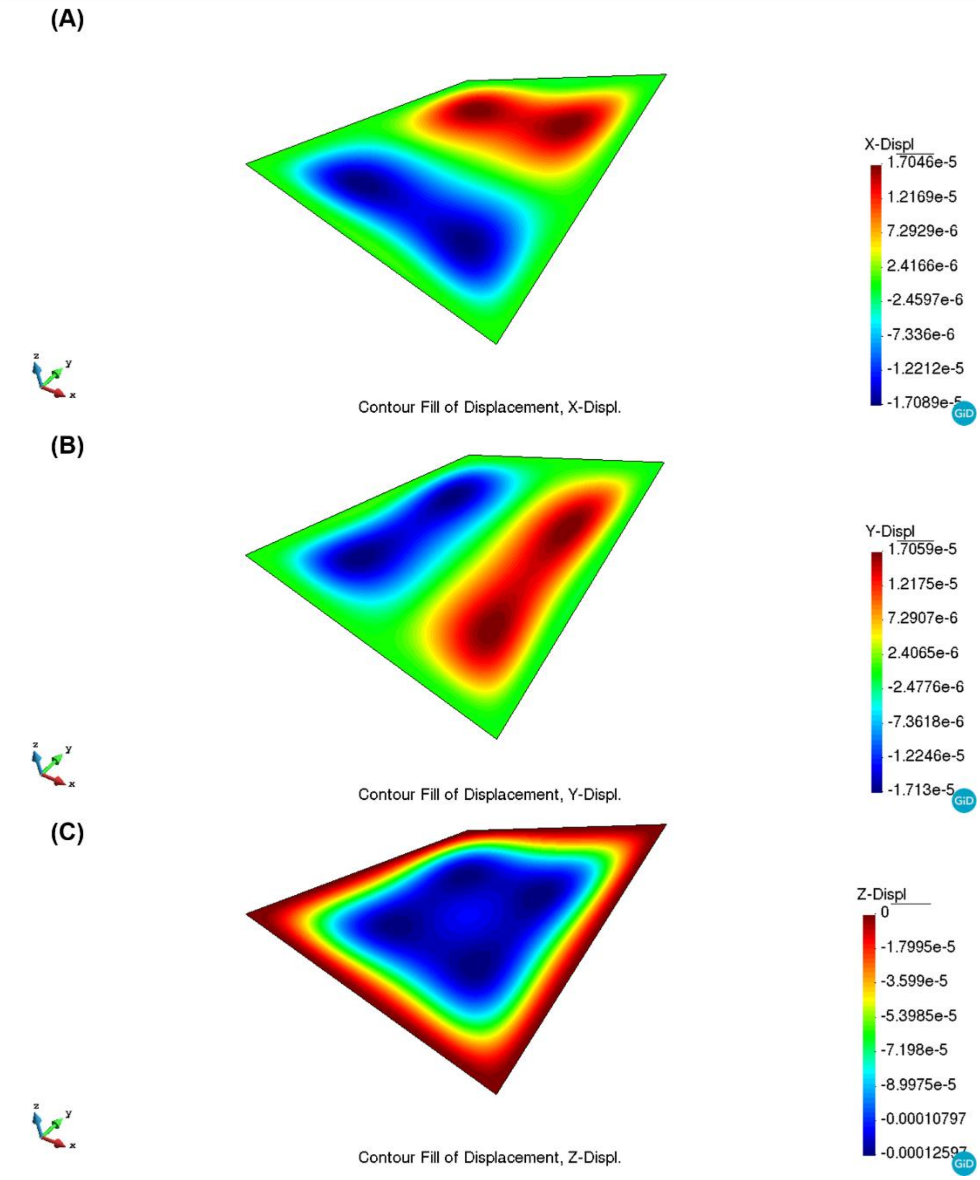

Figure 3. Displacement field in x direction (A), y direction (B) and z direction (C).

According to Figure 6, the greatest displacement is in the z direction. Such response is expected, since all the edges of the shell structure are fixed, and a self-weight load is applied. It is also important to mention the anti-symmetric concentration of displacements in x and y directions. Such behavior is directly related to the hyperbolic shape of the shell structure and the self-weight load. The shape of the structure also influences the membrane stress concentrations in the structure, which are related to the plane-stress state part of the Reissner-Mindlin flat shell formulation [1]. Figure 3 depicts the membrane stresses in x, y and xy.

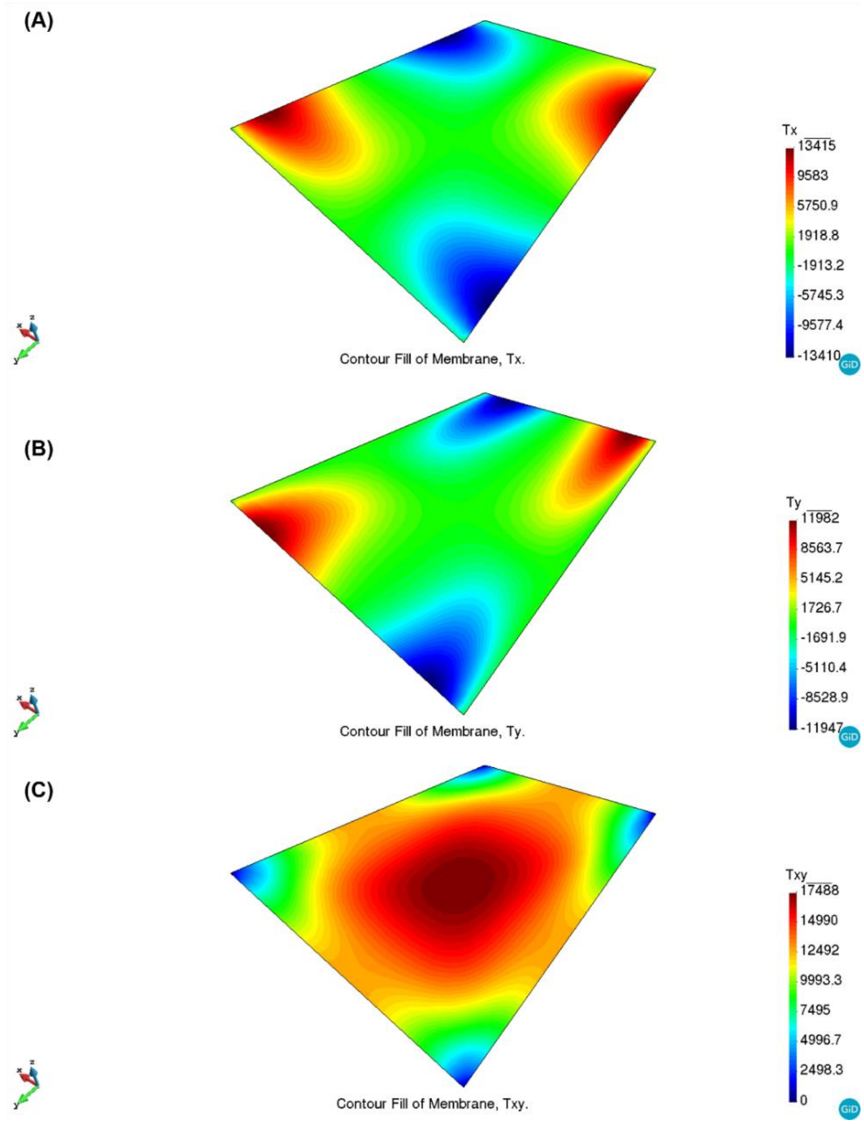

Figure 4. Membrane stress field Tx (A), Ty (B) and Txy(C).

According to Figure 3, the membrane stresses Tx and Ty also present ant-symmetric stress concentrations. Again, such behavior is due to the curvature of the structure, which greatly influences the response of the same. The membrane stress Txy has the highest concentration. This is due to the self-weight load and the Dirichlet boundary conditions applied to the structure. Also, the Reissner-Mindlin flat shell theory considers the moment and shear effects of the loading case on the structure [1]. Figure

4 depicts the moment stresses Mx and My and Figure 5 depicts the shear stresses Qx and Qy.

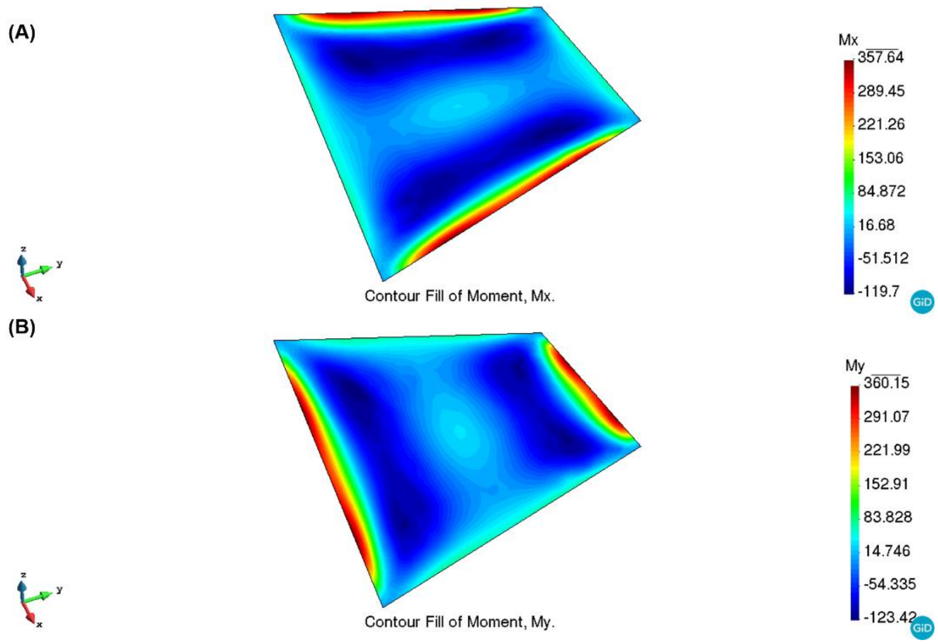

Figure 5. Moment stresses Mx(A) and My(B).

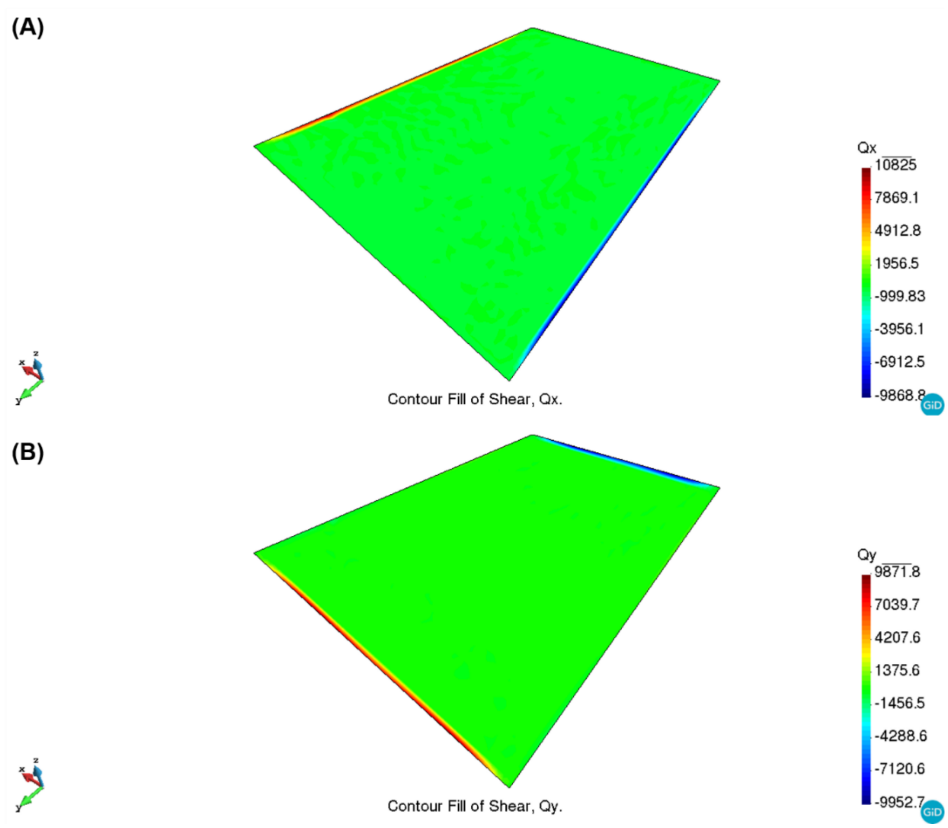

Figure 6. Shear stresses Qx (A) and Qy (B).

According to Figure 4 (A) and (B), most of the shell structure is under compression moment stress. This is beneficial to the integrity of the structure because the concrete offers greater resistance to compression loads. Figures 5 (A) and (B) depict a high concentration of shear stresses Qx and Qy close to the edges od the structures. Such concentrations are of opposite in sign, indicating a similar behavior similar to anti-symmetry. Such response is a consequence of the hyperbolic shape of the shell, the fixed edges and the self-weight load.

3 – Discussion and Conclusions

The Reissner-Mindlin flat shell theory is a powerful tool for structural analysis since it considers the effects of plane-stress state and the effects of plate bending with internal shear effects. Such theory enables the analysis of structures with complex geometry, such as the one analyzed in the present assignment. The structure analyzed in the present report presented a larger maximum displacement in the z direction, -0.00012597m, when compared to the maximum displacement in the other directions. Such behavior is due to the Dirichlet boundary conditions applied, fixing all the edges of the shell, and the self-weight load. Also, the membrane stresses presented an anti-symmetric behavior, with concentrations of compressive and tensile stresses on zones close to the edges of the structure. The shear stresses were concentrated only in a narrow region very close to the edge, and their concentrations also presented an anti-symmetric behavior. Last, the moment stresses were mostly compressive throughout the structure, indicating a suitable response for the use of concrete as the material of the shell. The analysis of the shell structure enabled the strengthen of knowledge regarding the plane-stress state and the Reissner-Mindlin plate theory.

4 – References

[1] – Presentation ‘Shells Notes v2’, Computational Structural Mechanics and Dynamics, Master of Science in Computational Mechanics, 2020.