Universitat Politecnica De Catalunya, BarcelonaTech
Masters in Computational Mechanics

Course
Computational Structural Mechanics and Dynamics

Assignment 8 on Shells

by

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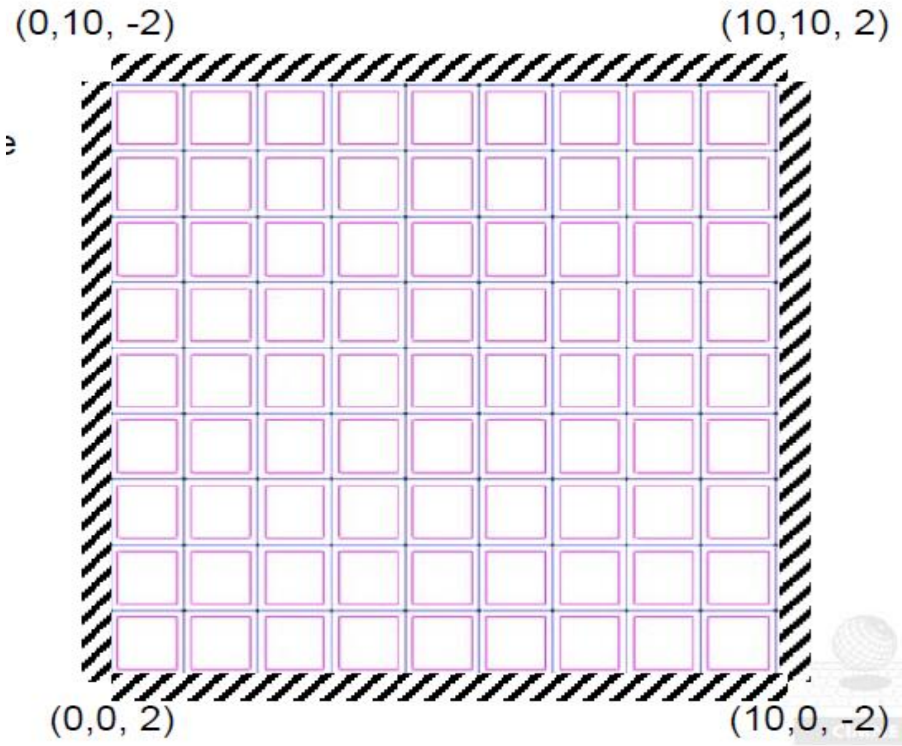
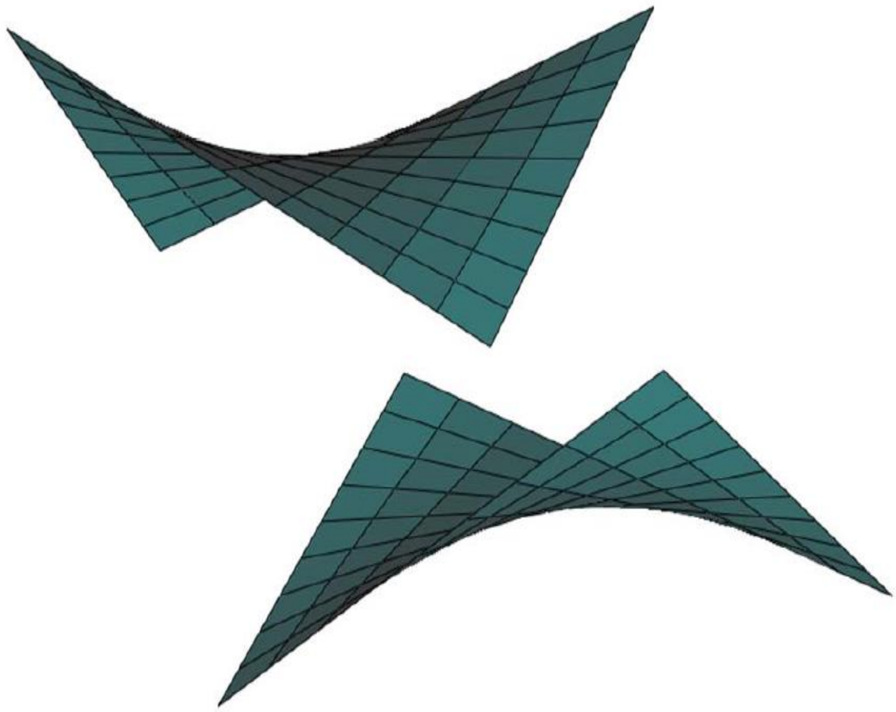
Exercise 1: Analysis of Shells with Plate Elements.

Ques. Analyze the following concrete hyperbolic Shell under self-weight.
Explain the behavior of all the Stresses presented.
Thickness of the plate: t = 0.1



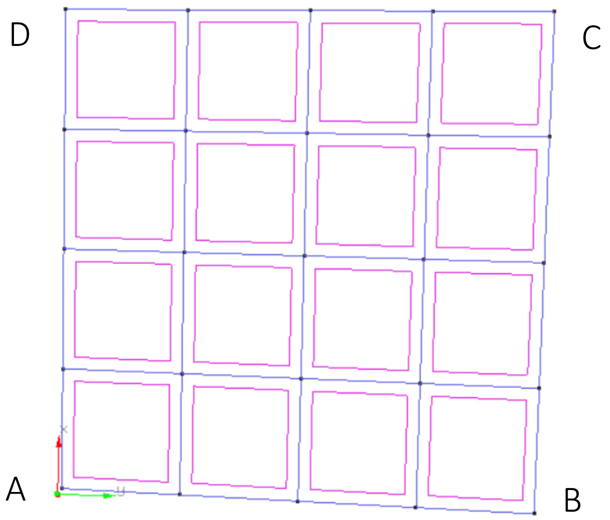


Solution:

Hyperbolic Shell: HP shells are doubly curved, non-developable and has non negative curvature. They are easy to construct using series of straight structural members, light-weight & efficient in minimizing material and also structural performance increases.

1. Analysis:

1.1. Geometry:



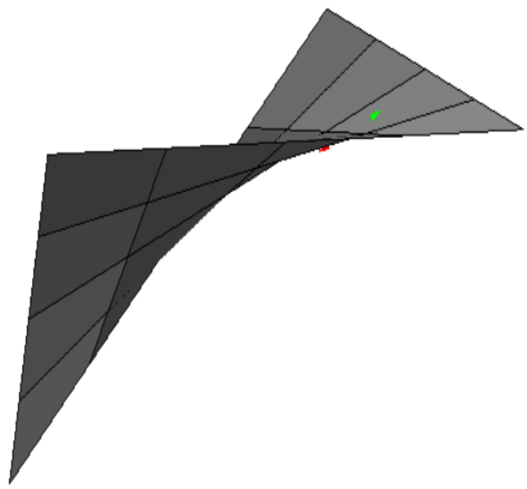


Fig 1.1: Geometry of Hyperbolic Shell

Coordinates of shell are: A (0 0 2), B (10 0 -2), C (10 10 2) & D (0 10 -2).

After defining the geometry, we need to solve the Shell Problem. Therefore, MAT-fem_shells module is selected by using the following commands: Data/Problem Type/MAT-fem_shells.

1.2. Boundary Conditions:

All sides of hyperbolic shells are clamped.

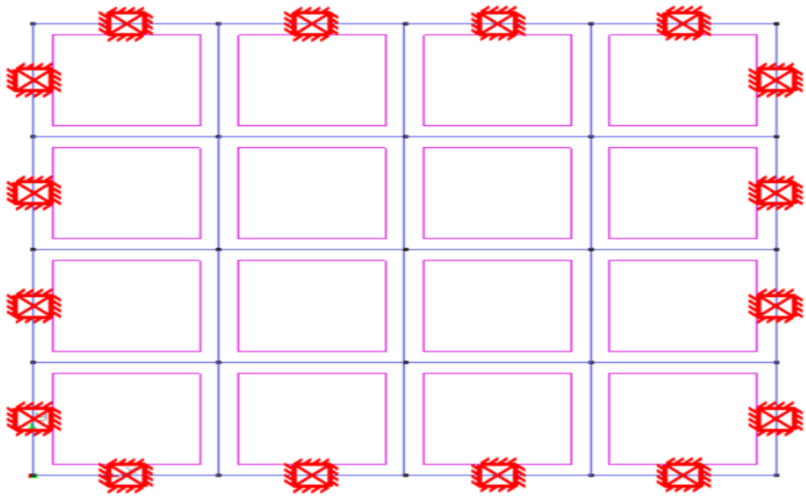


Fig 1.2: Boundary Conditions

1.3. Material:

Concrete Material is chosen for the whole domain with following mechanical characteristics, E = 3.0 e10 N/m², $\nu = 0.2$ & t = 0.1.

1.4. **Meshing:** Type of Mesh: Structured Mesh
Element Type: Mesh of Triangular elements.
Triangular Elements: Linear elements with 3 nodes (Normal).

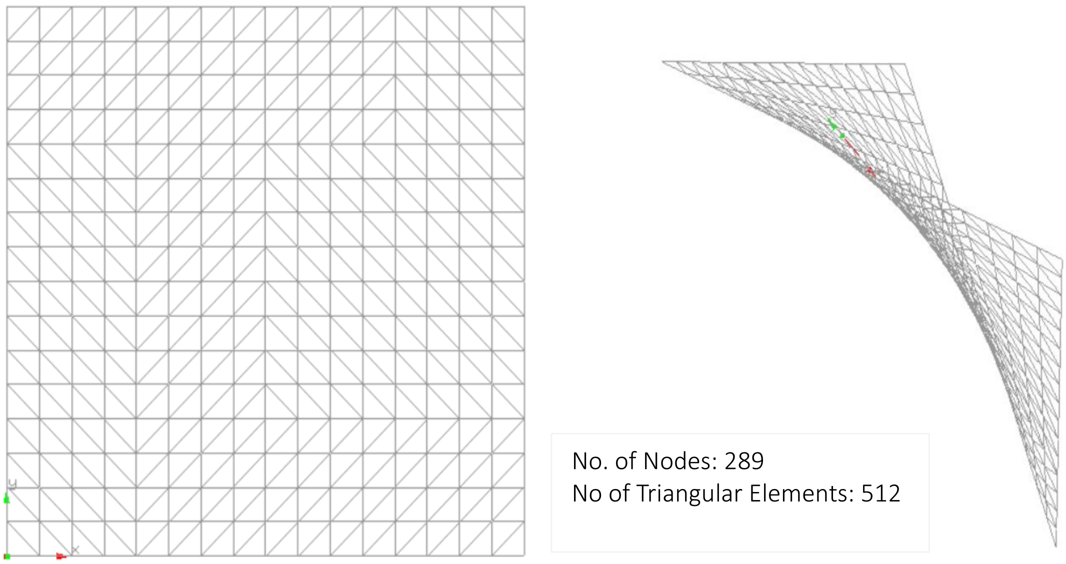


Fig 1.3: Meshed Geometry

2. **Post Processing:**

2.1. **Calculate:** After mesh generation, Matlab file is exported to Matlab. Algorithm of Hyperbolic shells with triangular mesh is set to RUN and calculate the values. That file is again imported to GID for Post Processing. The following figures shows the obtained distribution of displacements & stresses on the Hyperbolic Shell.

2.2. **Results:** It is curved hyperbolic shell with straight edges at the end. This curve shape reduces shell tendency to buckle in compression.

a. **Displacements:** [Disp. X, Y & Z] Displacements shows Global deformation i.e. it uses Global Coordinate System. In displacement X & Y, deformation bends is opposite directions while in Z displacement, deformation is at the centre.

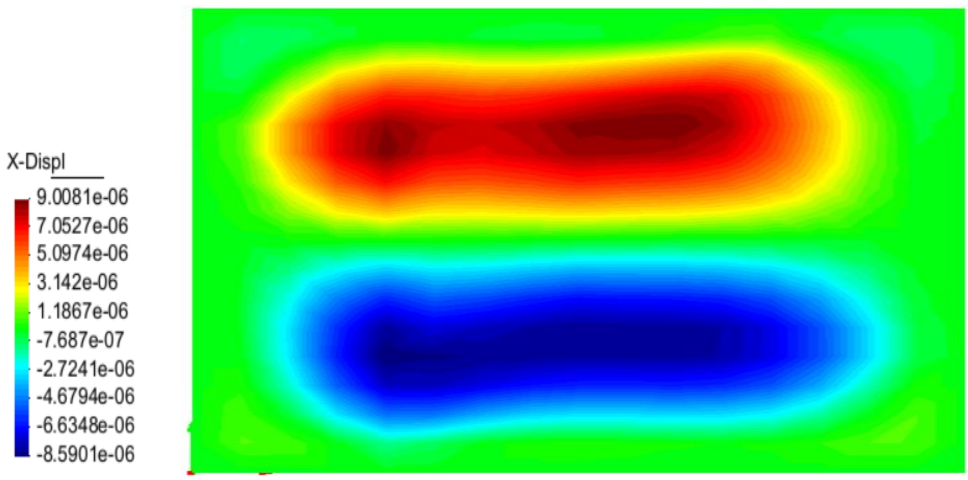


Fig 1.4: X Displacement

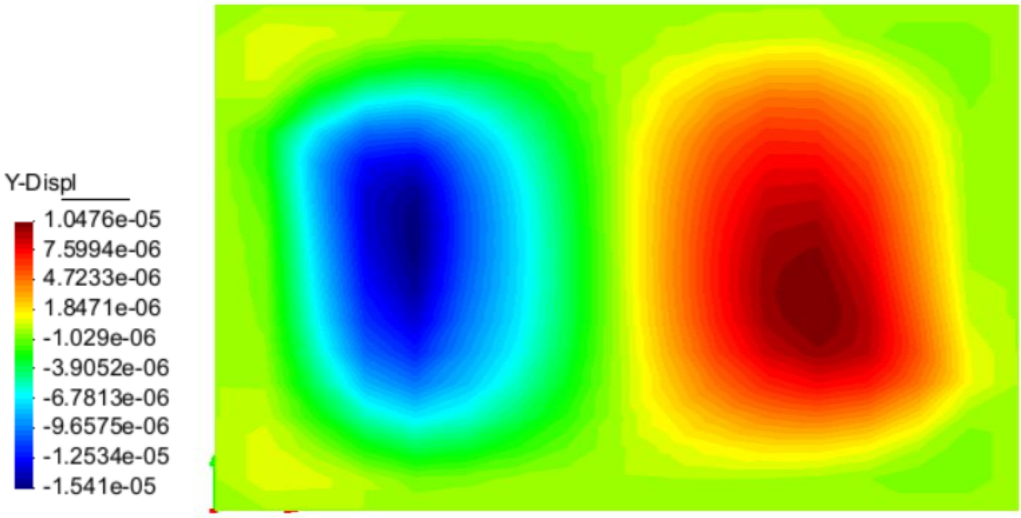


Fig 1.5: Y Displacement

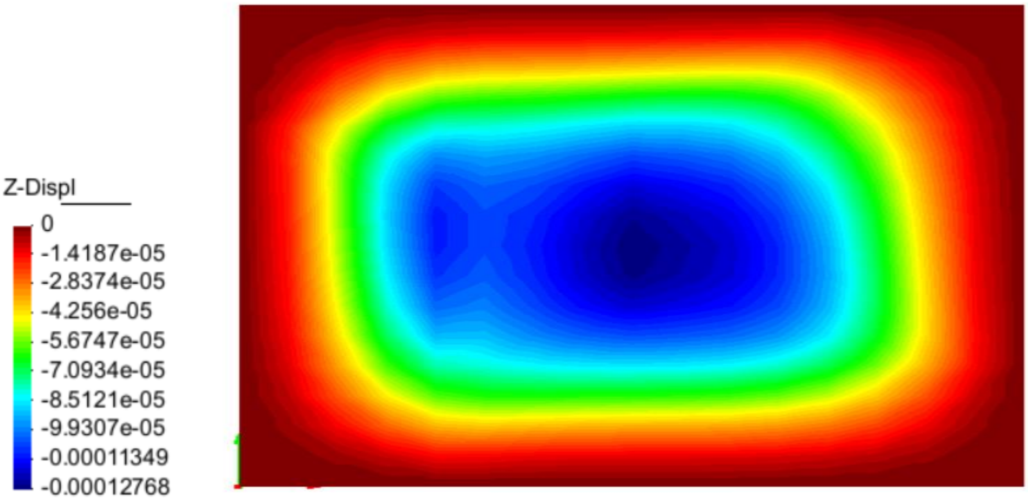


Fig 1.6: Z Displacement

a. **Rotations:** [Rot θ_x , θ_y] Rotations uses Local cordinate system. Rotations in X & Y directions shows rotations opposite to each other.

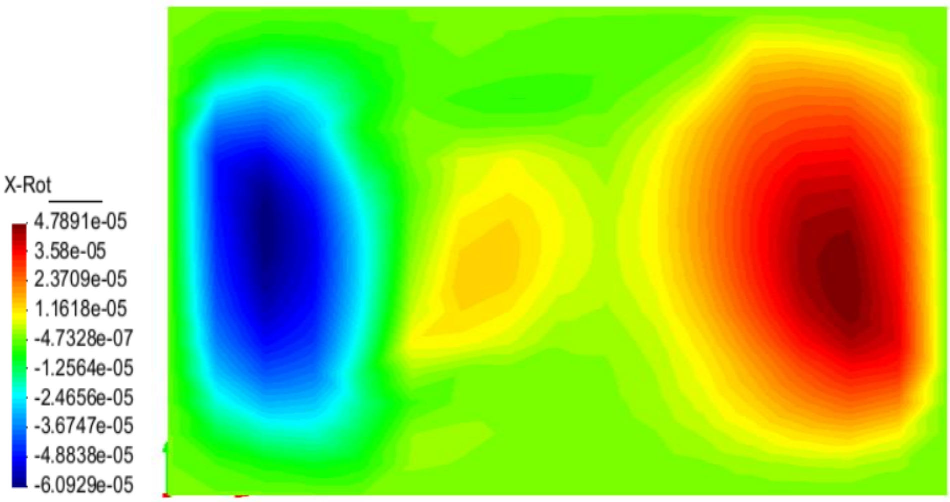


Fig 1.7 : θ_x Rotation

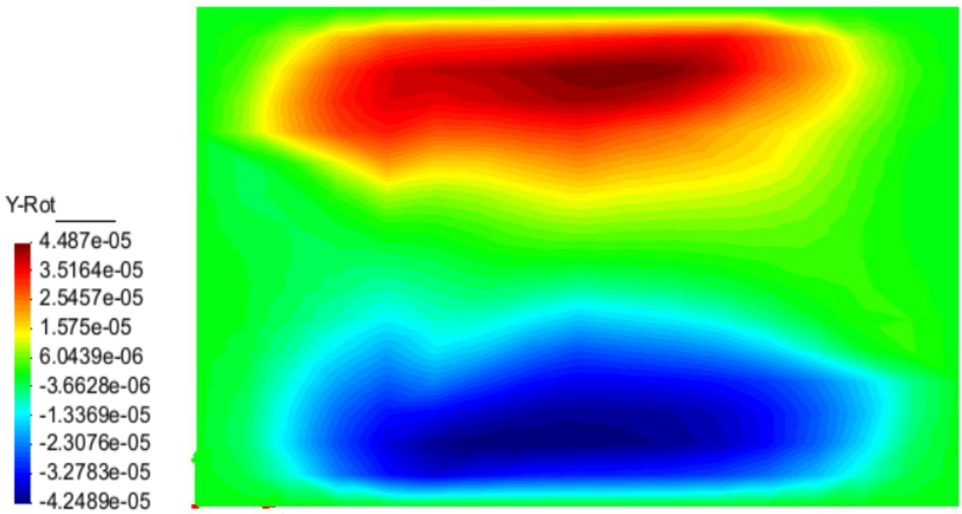


Fig 1.8: θ_y Rotation

Stresses (Membrane, Bending Moment & Shear) uses Local Cordinate System, because in the algorithm B matix is defined in local cordinate system.

b. **Membrane:** [Mem T_x, T_y & T_{xy}] The curved edge acted as compression arche which carried shear forces and then transferred them to the end straight edges through the shell itself. It observed in membrane stress in X & Y direction that stresses are maximum & minimum in opposite directions.

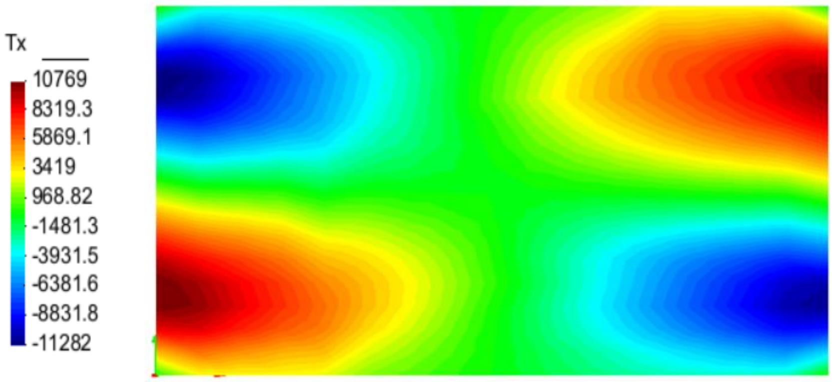


Fig 1.9 : T_x Membrane

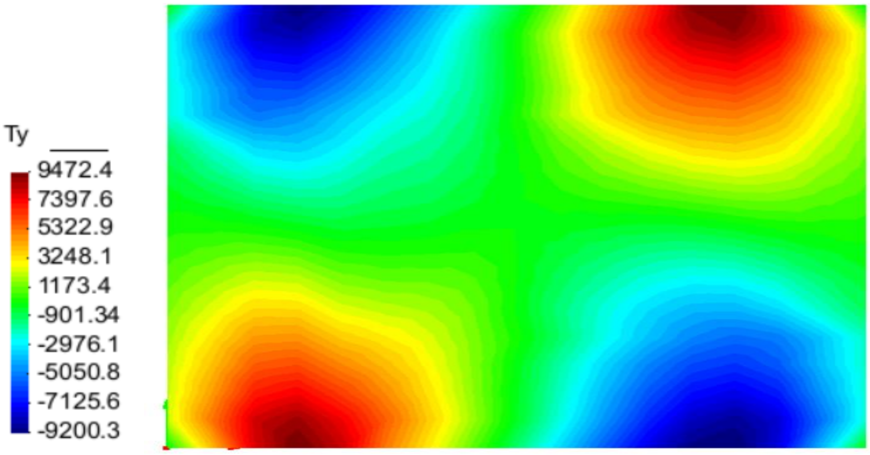


Fig 1.10 : T_y Membrane

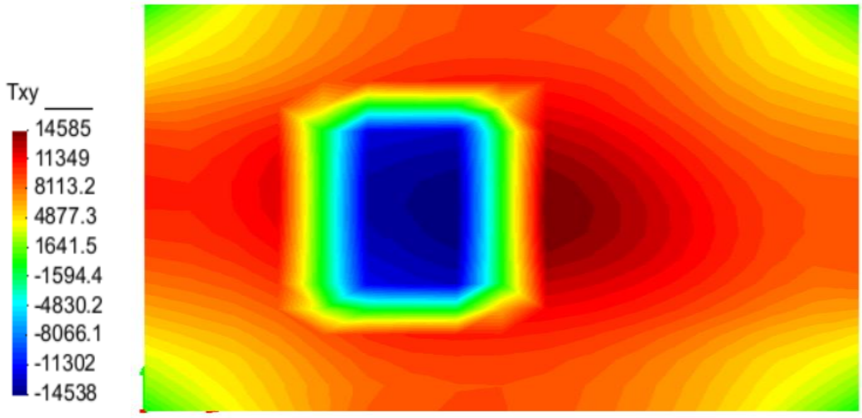


Fig 1.11 : T_{xy} Membrane

c. **Bending Moment:** [Moment M_x, M_y & M_{xy}] It depends on geometric parameters and boundary conditions. Clamping all the sides of the shells forces it to bend at the edges itself. And as the shell is curved, bending moment is minimum at the center and maximum at the straight edges. It can withstand unequal load i.e. the ratio of dead load to live load is low.

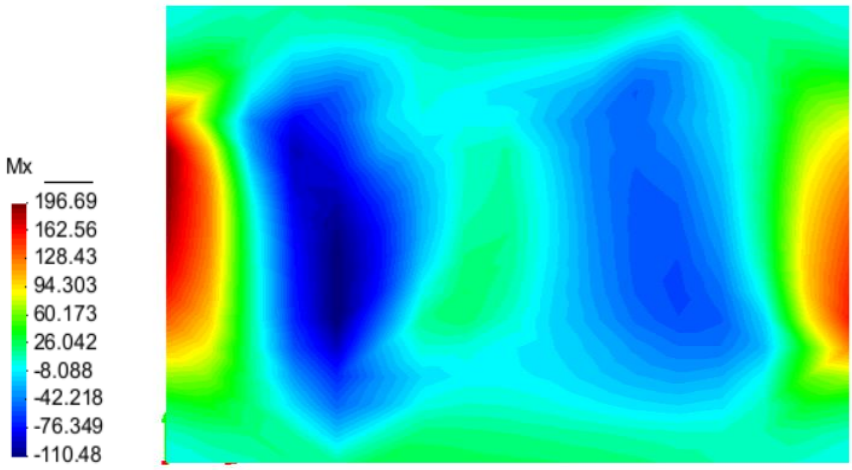


Fig 1.12 : M_x Moment

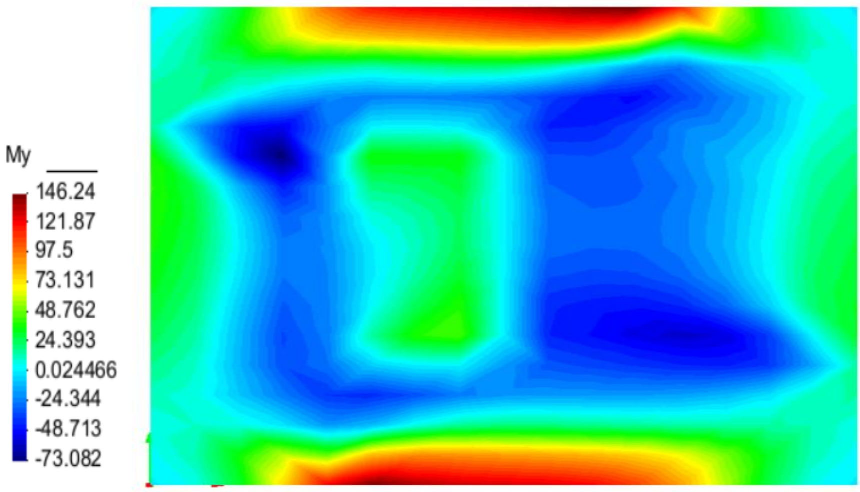


Fig 1.13 : M_y Moment

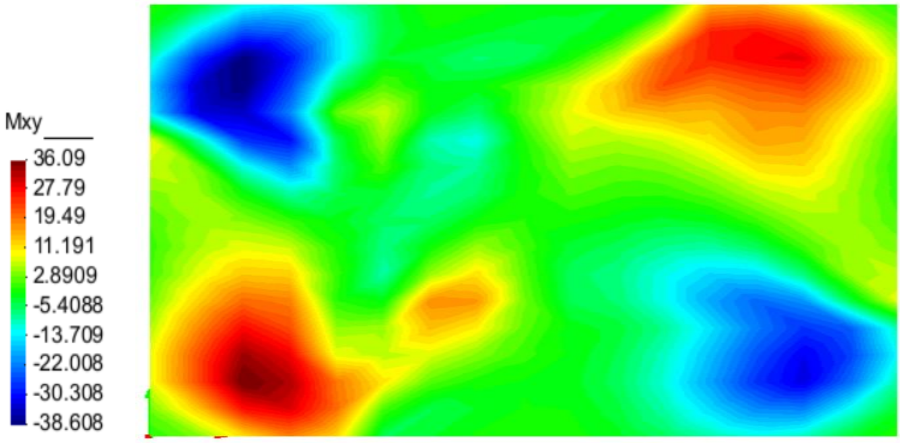


Fig 1.14 : M_{xy} Moment

d. **Shear Stress:** [Stress Q_x & Q_y] As stated in membrane stress that shear is transferred to the end edges. So transversed shear (Tensile stress) is observed only at end edges in X & Y direction.

Fig 1.15 : Q_x Shear Stress

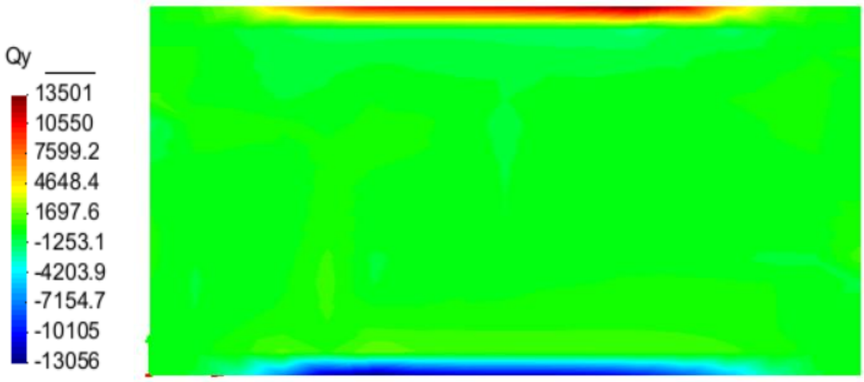


Fig 1.16 : Q_y Shear Stress

----x----x----x----