# ASSIGNMENT 8

## Computational Structural Mechanics and Dynamics


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**ADVISOR: -Prof.  Francisco Zárate**

**Goal:** To analyse the given concrete hyperbolic Shell under self-weight and to study the behaviour of all the Stresses presented.

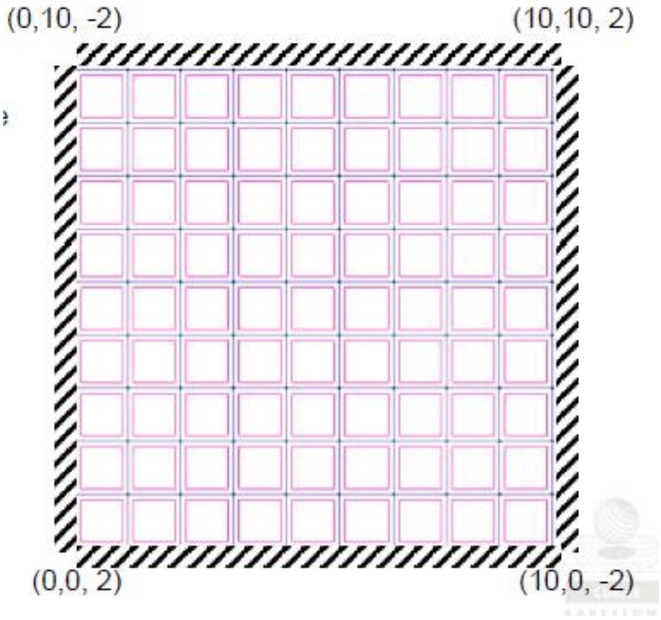



**Figure 1: The given Shell with thickness 0.1 m**

**Background:**

A shell can be seen, in essence, as the extension of a plate to a non-planar surface. The non-co-planarity introduces axial (membrane) forces in addition to flexural (bending and shear) forces, thus providing a higher overall structural strength. A "shell element" combines a flexural (bending and shear) behaviour and an "in-plane" (membrane) one. The membrane state induces axial forces contained in the shell middle surface. The behaviour of flat shell elements depends in most cases on the accuracy of the individual plane stress and plate elements selected.

The given hyperbolic shell, in the constructional sense, it is a thin shell of a great bearing capacity and wide usability in spatial structures, either as a complete form or in parts. To solve the given Shell the Reissner-Mindlin flat shell theory for thin/thick shells has been considered. The shell surface is discretized into 4-noded QLLL flat shell quadrilateral combining the 4-noded plane stress quadrilateral and the QLLL plate element. Figure 2 shows the discretization.

**Material Properties:**

**E**= 3 *e10 Pa, $\gamma = 0.2$ ; Self weight is considered. Thickness=0.1m

$\rho g = 25000 \frac{N}{m3}$

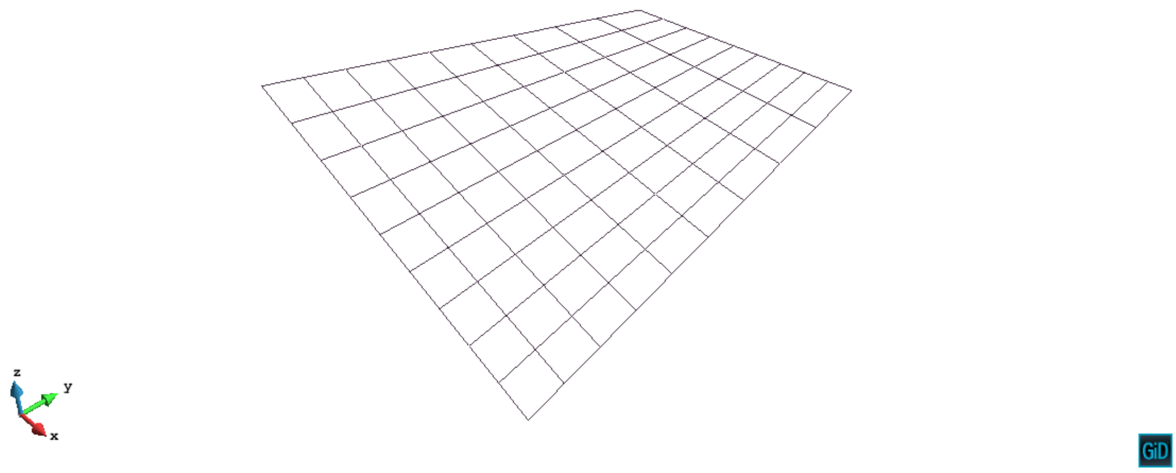



**Figure 2:** Shell discretized with 4-noded QLLL flat shell quadrilaterals

**Boundary Conditions:**

As the Shell is clamped along its 4 edges, all DOFs (**a**i) at nodes laying on a clamped edge are prescribed to a zero value.

The exported .m file is submitted to the supplied code for the adopted method to obtain the various solutions for the given Shell. The solutions have been depicted below.

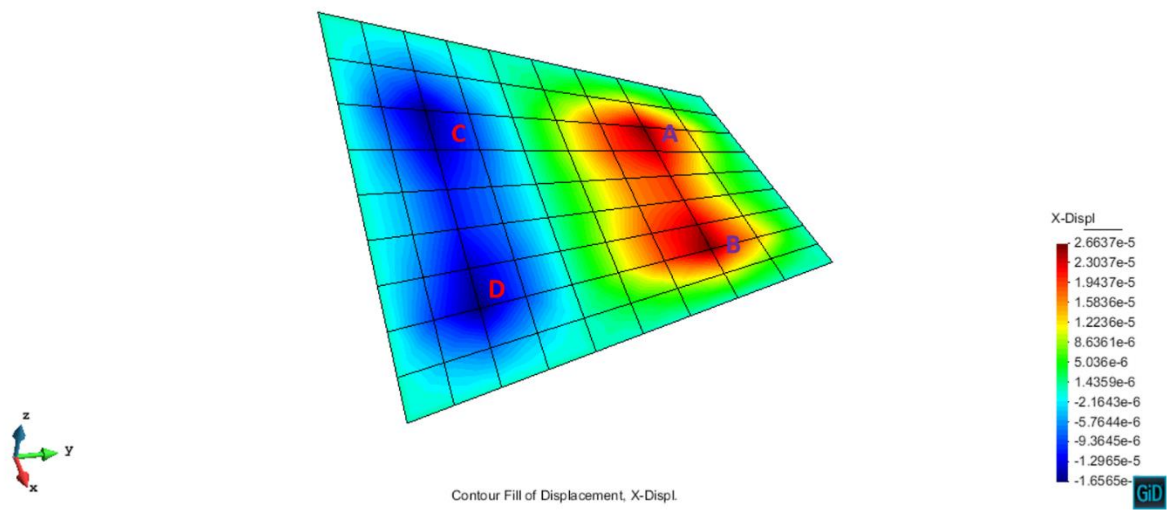



**Figure 3:** Global X displacements

In the regions A and B in the Shell the X displacements are higher (Positive), and they are low (Negative) in the regions of C and D.

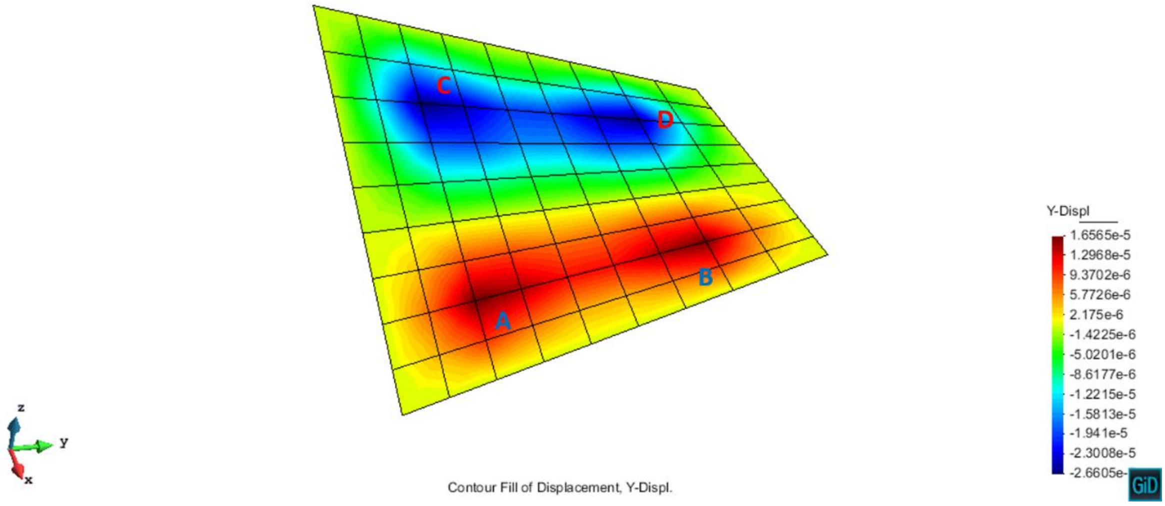



**Figure 4:** Global Y Displacements

In the regions A and B in the Shell the Y displacements are higher (Positive), and they are low in the regions of C and D (Negative).

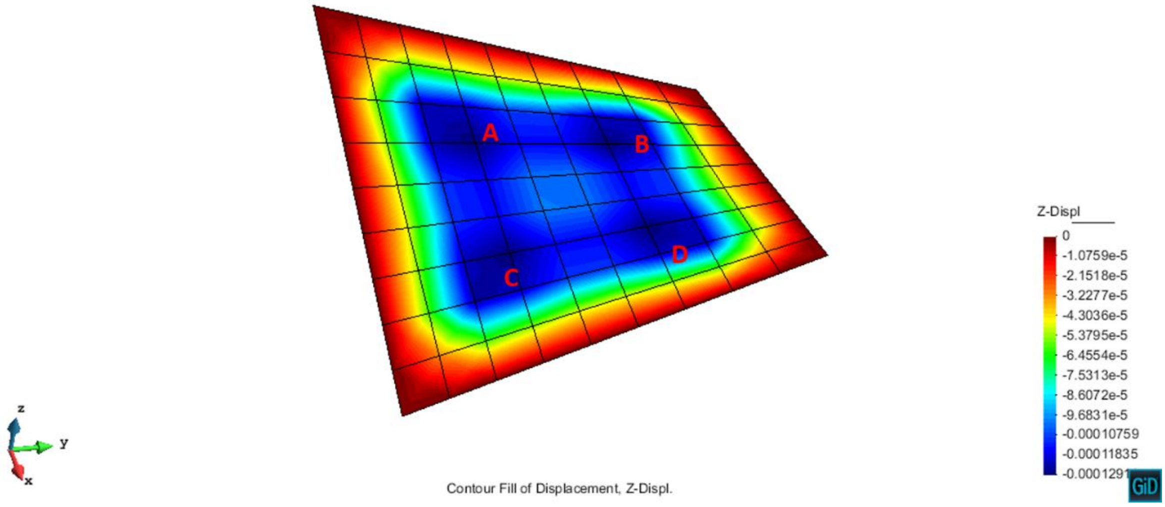



**Figure 5:** Global Z displacements

In the regions A, B, C and D in the Shell the Z displacements are higher (Negative).

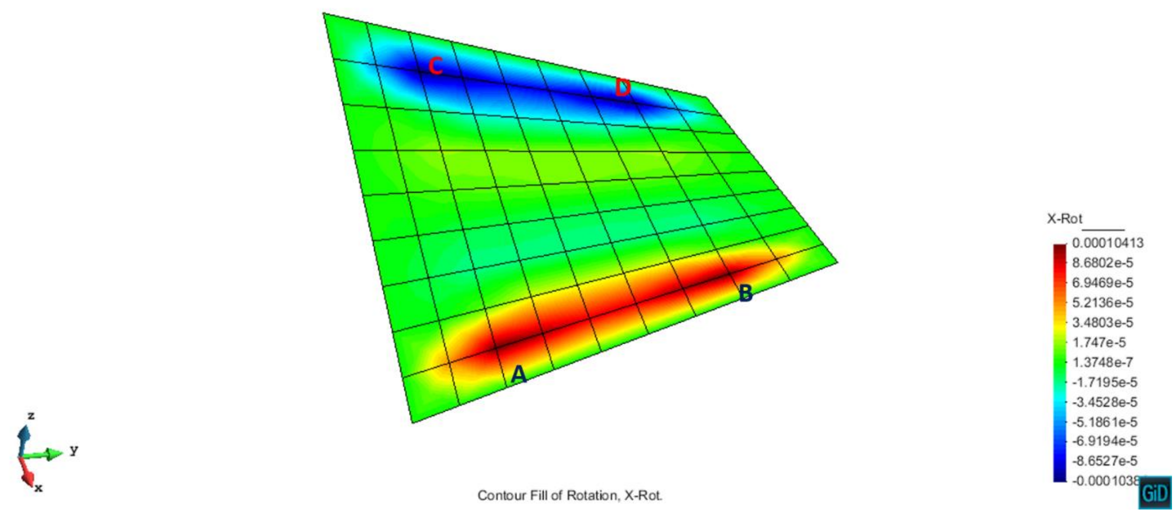



**Figure 6: $\theta_x{}'$ Rotation**

In the regions A and B in the Shell (along the X direction) the Local X rotations are higher (Positive), and they are low in the regions of C and D (Negative).

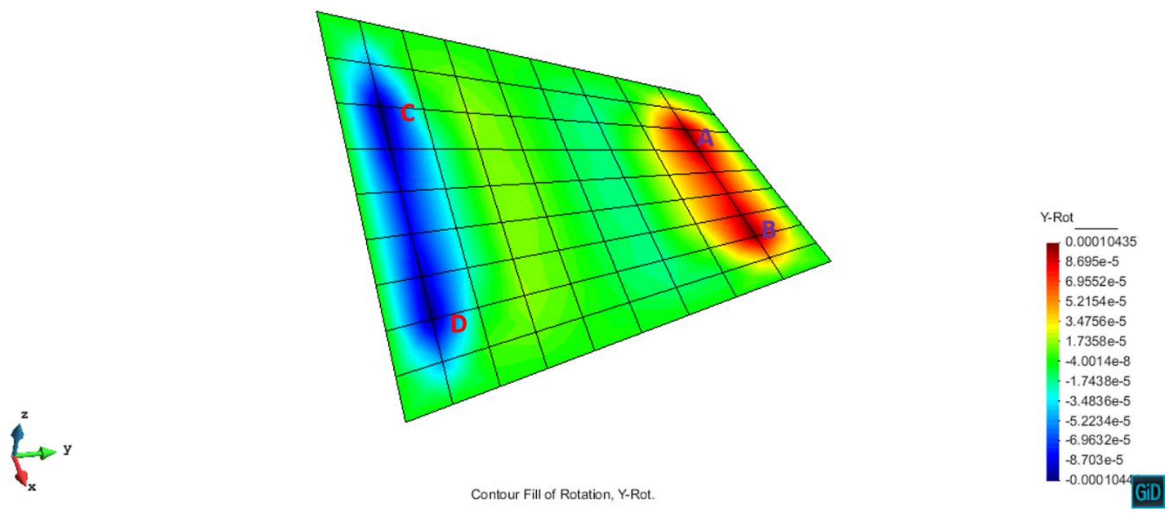



**Figure 7: $\theta_y{}'$ Rotation**

In the regions A and B(Along the Y) in the Shell the Local Y rotations are higher (Positive), and they are low in the regions of C and D (Negative).

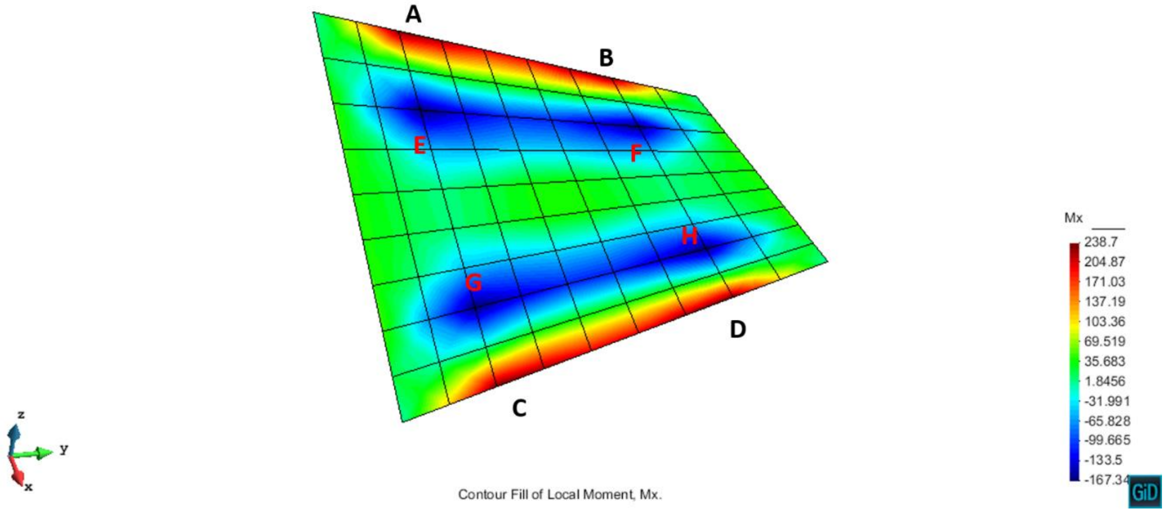



**Figure 8: $M_x{}'$ Stress**

In the regions A, B, C and D in the Shell the Local moment $\boldsymbol{M_x}$ are higher (Positive), and they are low in the regions of E, F, G and H (Negative).

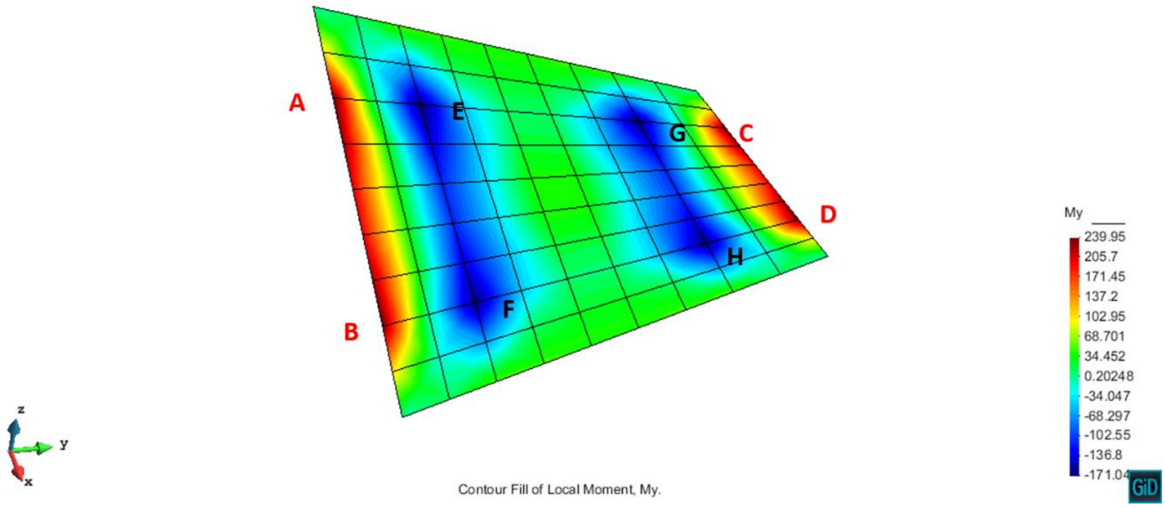



**Figure 9: $M_y{}'$ Stress**

In the regions A, B, C and D in the Shell the Local moment $\boldsymbol{M_y}$ are higher (Positive), and they are low in the regions of E, F, G and H (Negative).

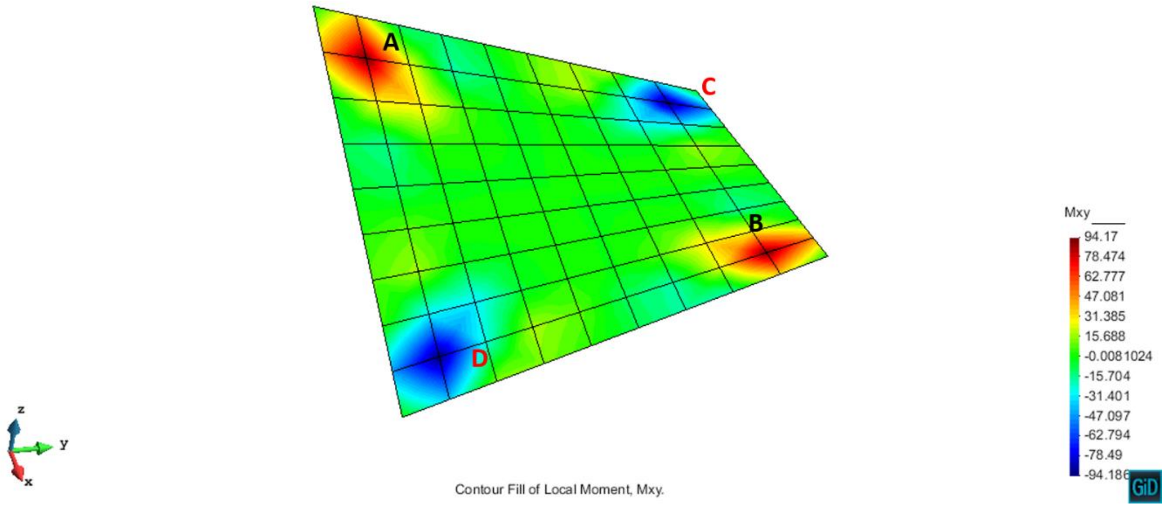
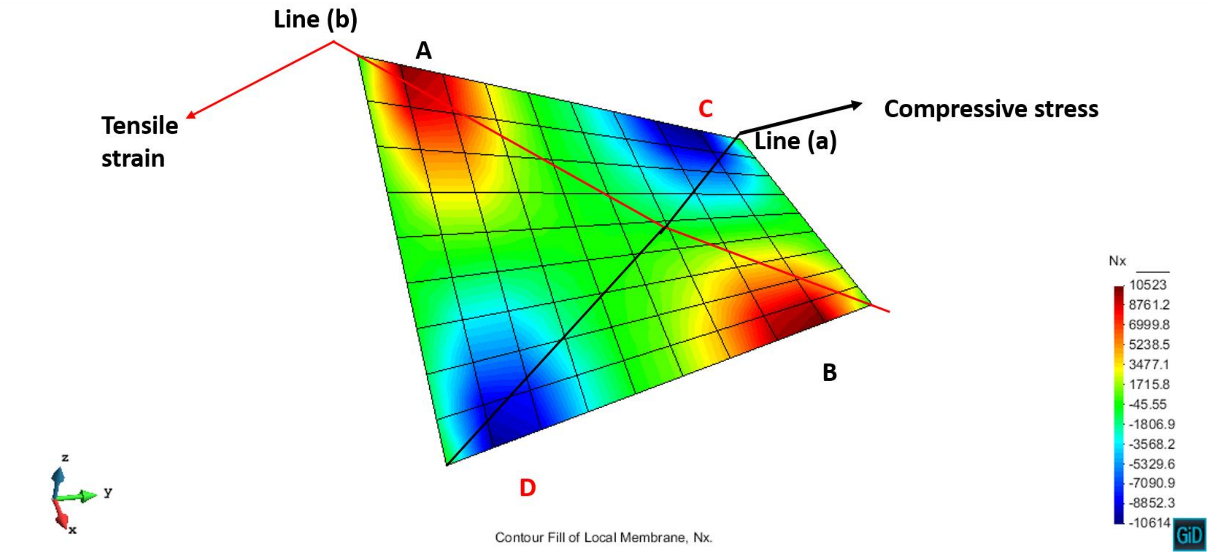



**Figure 10: $M_{xy}{}'$ Stress**

In the regions A, B in the Shell the Local moment $\boldsymbol{M_{xy}}$ are higher (Positive), and they are low in the regions of C, D (Negative).

**Membrane Stresses:-**

Double-curved surfaces usually have satisfactory bearing capacities, while in the given hyperbolic paraboloids Shell (HP) it is even greater, as the convex curvature stiffens in a way the concave curvature (Fig. 11). Compressive stresses appear along the line a, and tensile strains are formed along the line b. The shell principal stresses are created alongside the vertical sections, which make the angle of $45^0$ with the ruling lines. Placing edge elements or ribs that accept the compressive or tensile stresses for the designed surface geometry most often solves the reception of shearing forces on the edges. Edge elements may be avoided in highly curved shells. In principle, care should be taken of the edge elements load, that is, their dead weight and its impacts. This is particularly important in cases where they are asymmetrically loaded. In most cases, hyperbolic paraboloids (HP) shells have great safety against bulging due to their curvatures.



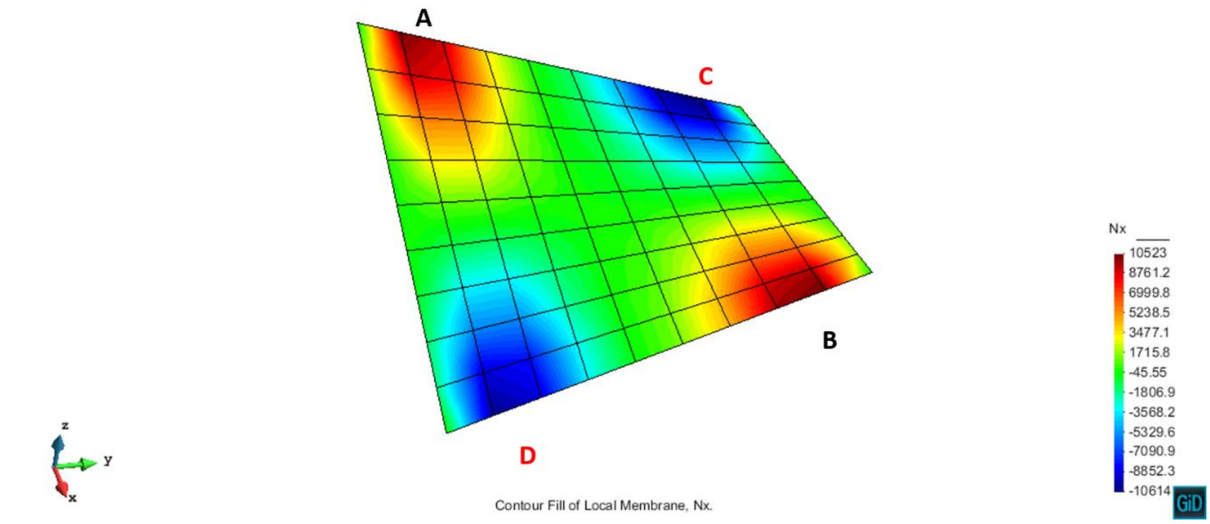




**Figure 11: Local Membrane, $N_x$ Stress**

In the regions A, B in the Shell the Local membrane, $\boldsymbol{N_x}$ stress are higher (Tensile, Positive), and they are low in the regions of C, D (Compressive, Negative).

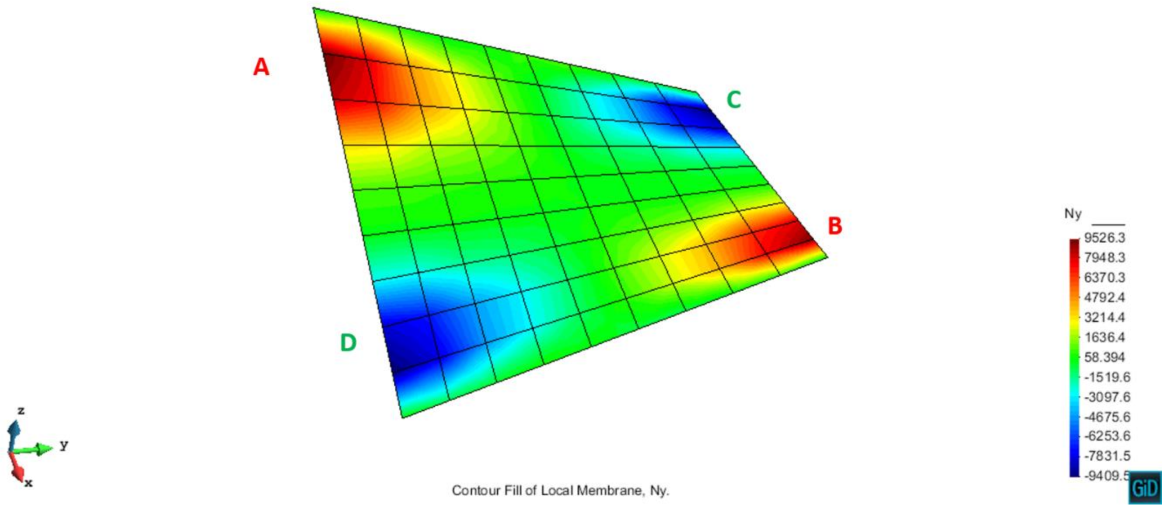



**Figure 12: Local Membrane, $N_y$ Stress**

In the regions A, B in the Shell the Local membrane, $\boldsymbol{N_y}$ stress are higher (Tensile, Positive), and they are low in the regions of C, D (Compressive, Negative).

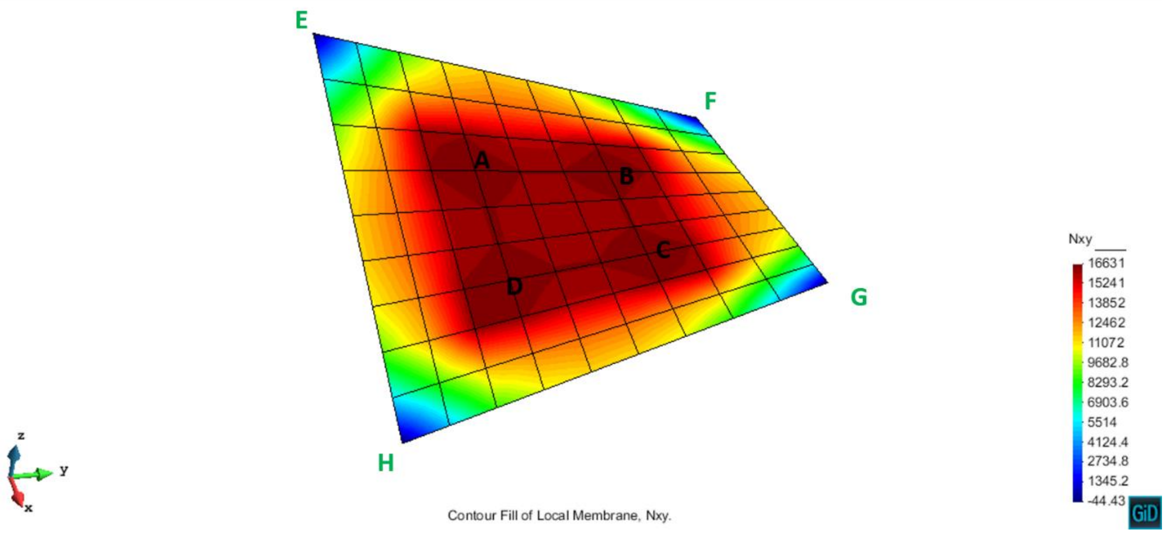



**Figure 13: Local Membrane, $N_{xy}$ Stress**

In the regions A, B, C, D in the Shell the Local membrane, $\boldsymbol{N_{xy}}$ stress are higher (Tensile, Positive), and they are low in the regions of E, F, G, H (Compressive, Negative).

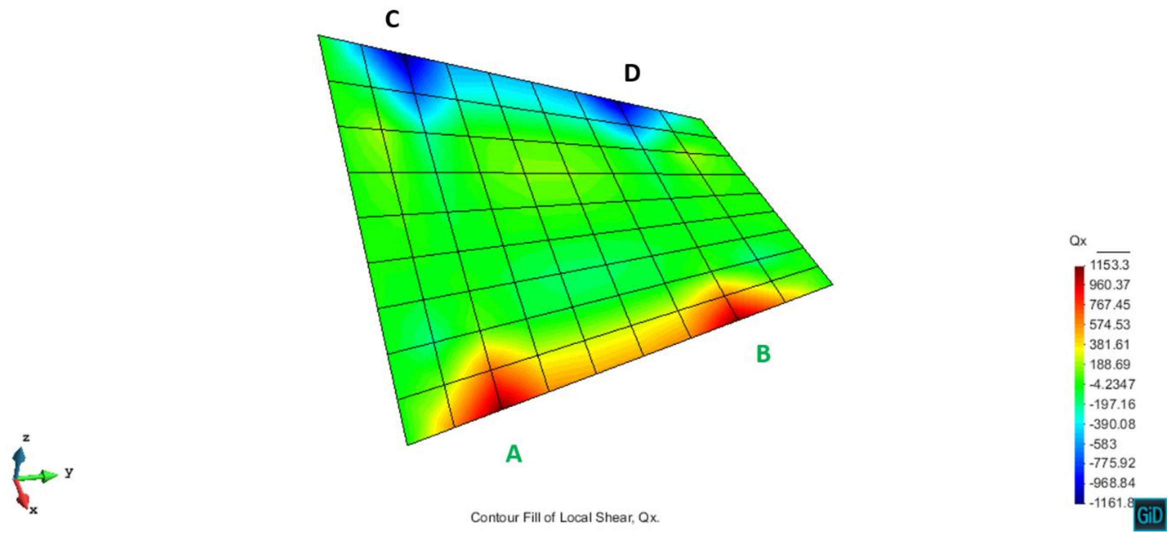



**Figure 14: Local Shear, $Q_x$**

In the regions A, B in the Shell the Local Shear, $\boldsymbol{Q_x}$ stress are higher (Positive), and they are low in the regions of C, D (Negative).

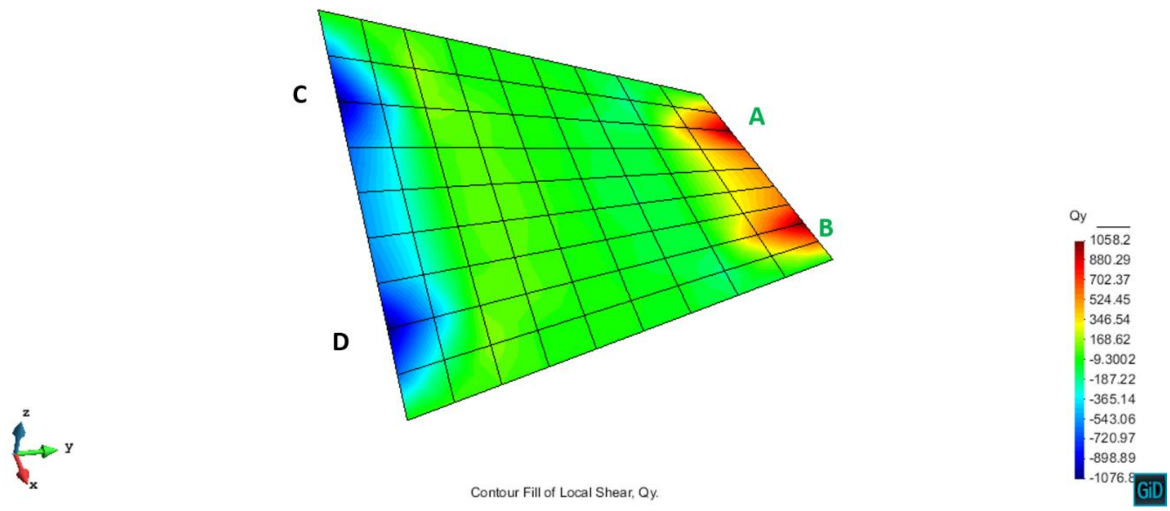



**Figure 15: Local Shear, $Q_Y$**

In the regions A, B in the Shell the Local Shear, $\boldsymbol{Q_y}$ stress are higher (Positive), and they are low in the regions of C, D (Negative).