Shell

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1. Introduction

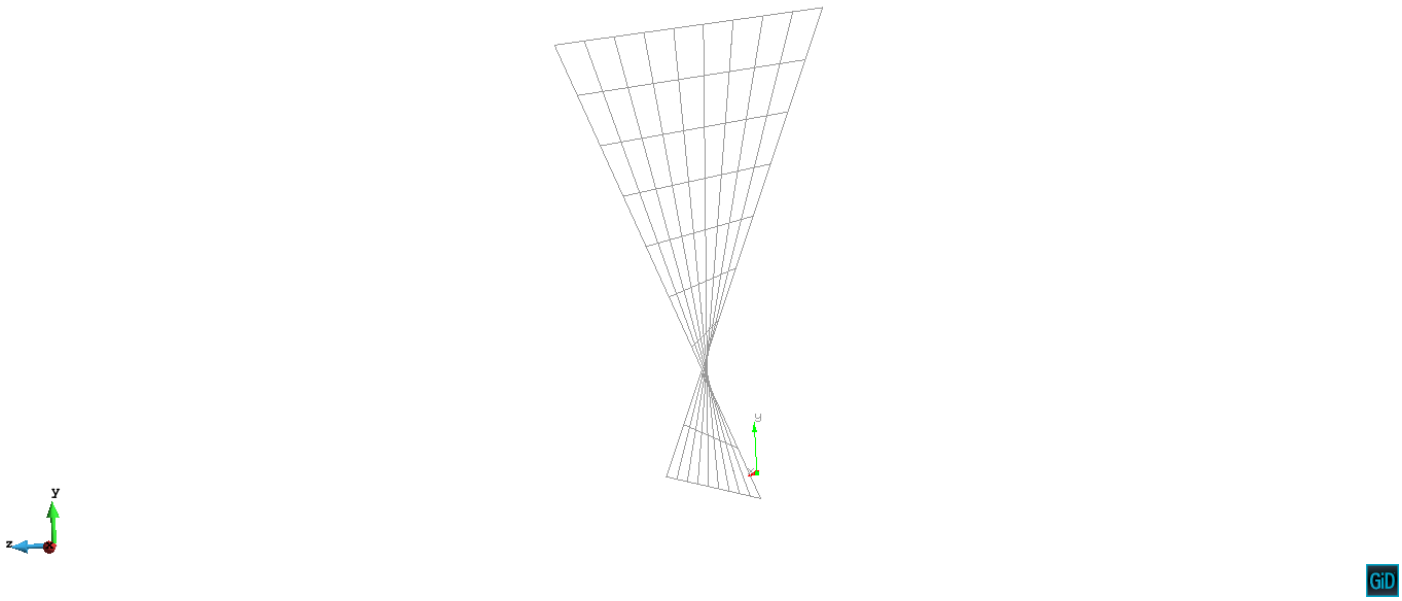

Figure 1. The Model

This shell model and the boundary conditions are both symmetric. And we only apply the self-weight whose direction is $-z$, so the force is symmetric on xy plane. On the basis of symmetricity, the results would be also symmetric as we can see in following parts.

Like arch structures, the shell structures will transform the loads to mainly membrane stress. By achieving this, this type of structure can make the best of the material strength to help us save the materials. And the utilization of the rationality of space structure brings us with the high strength and rigidity. Consequently, the special force mean of shell structure can successfully help the shell structures solve the weakness of out of plane problem. With light structure self-weight, high rigidity and high bear capacity, the shell structure can make large span structure possible.

Because of the advantages of shell structures, there are so many applications like large span buildings, airports, stations and so on.

2. Displacement and rotation

(1) Displacement

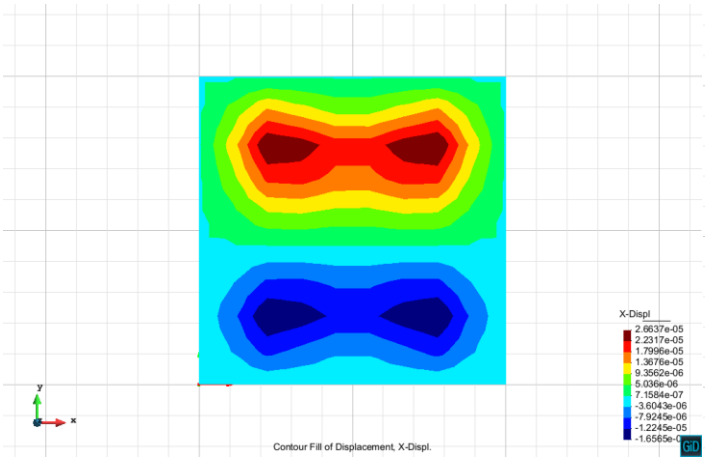

Figure 2. Displacement X

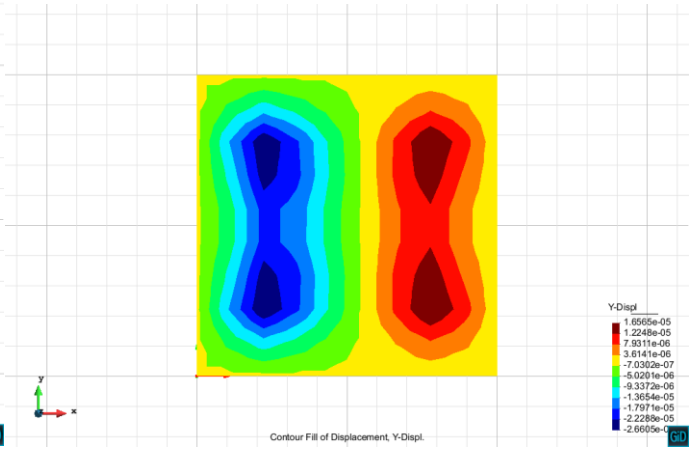

Figure 3. Displacement Y

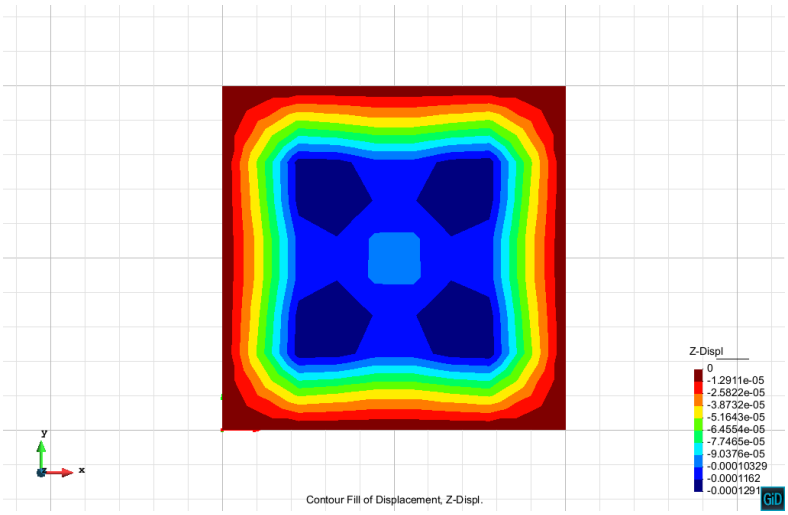

Figure 4. Displacement Z

From above results, we can find that the displacement field on x direction and y direction are same. The absolute values of maximum and minimum displacements are same. The displacement field of z direction is symmetric.

(2) Rotation

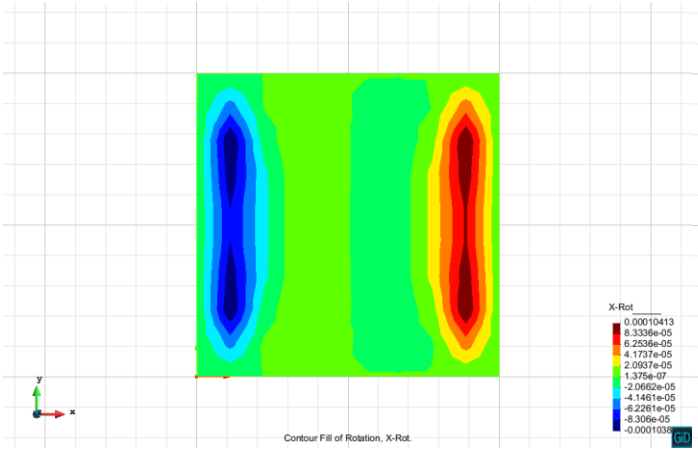

Figure 5. Rotation X

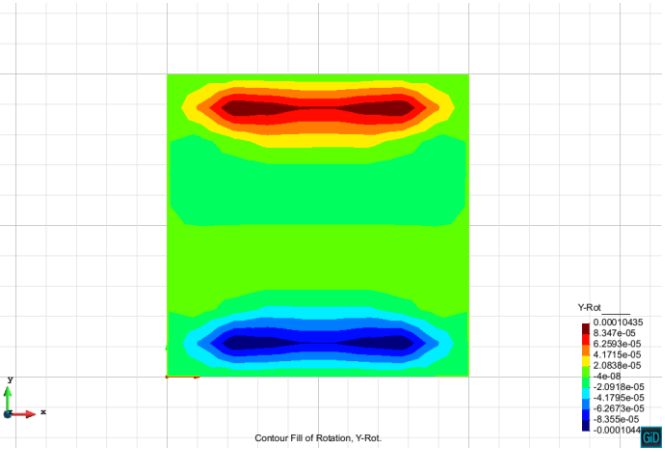

Figure 6. Rotation Y

The rotations on the areas near boundaries are highest.

3. Stress

The main stresses of shell structure include membrane stress and bending stress. And the membrane stress is the most important one. When the membrane stress is the main stress, we can utilize material strength most efficiently, meaning that we can save materials. The advantage of shell structure will also present in the aspect like making the structure have more reasonable forces because the bending stresses is more dangerous than membrane stress for shell structures. By using shell structures, we can transform the loads to the membrane stress which can be endured by shell structures more efficiently as said before. This is why we can design larger span buildings like larger stadium. These advantages of shell structures all come form their reasonable forces system, which means that the membrane stress is the main stress.

(1) Membrane stress

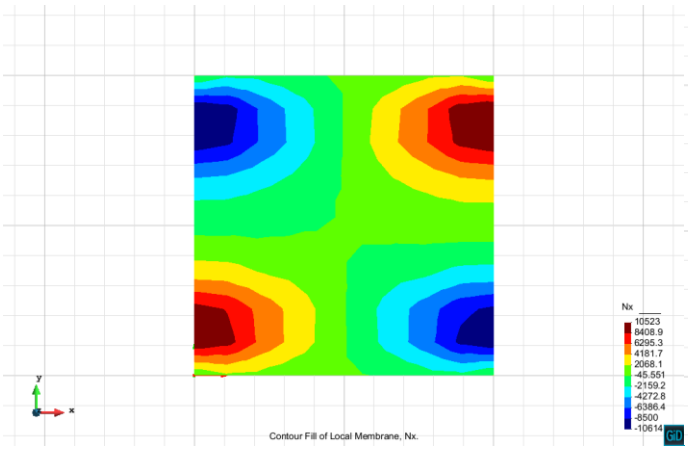

Figure 7. Membrane stress N_x

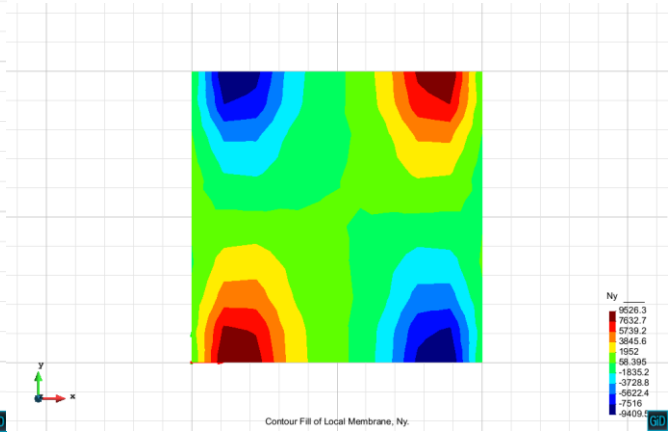

Figure 8. Membrane stress N_y

Figure 9. Membrane stress N_{xy}

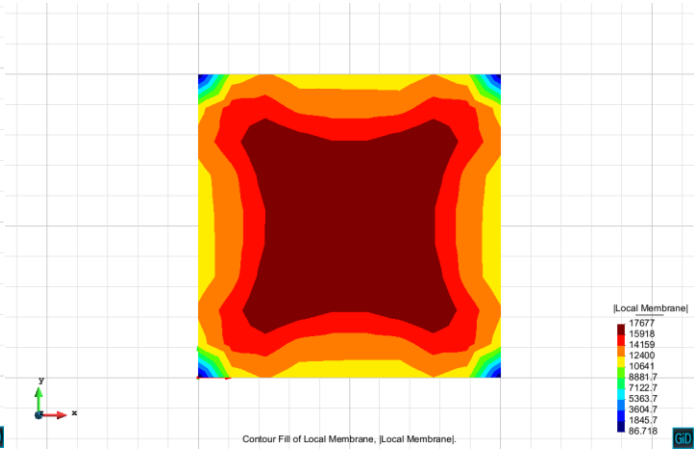

Figure 10. Membrane stress N_{all}

Above figures show that:

① For membrane compressive and tensile stress, the highest value areas are near the corners. In our example, actually we have two lines connecting the diagonal points. One is Tensile stress line and another one is Compressive stress line, which we can see in above figures.

② For membrane shear stress, the highest value area is in the middle area of the structure..

③ For the total stress, the most dangerous area is the middle red area.

(2) Moments

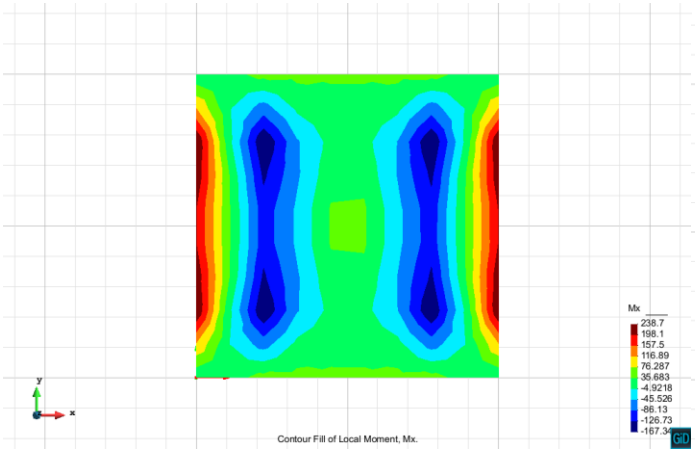

Figure 11. Moment M_x

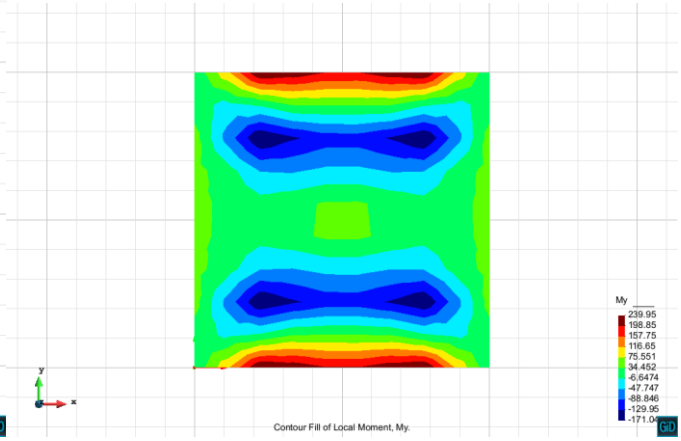

Figure 12. Membrane stress M_y

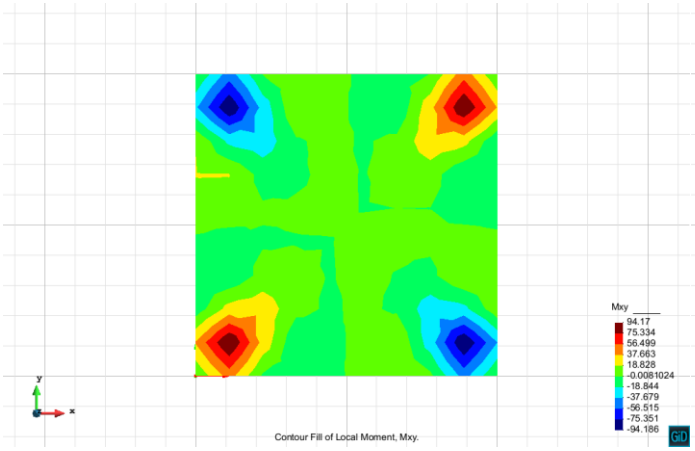

Figure 13. Moment M_{xy}

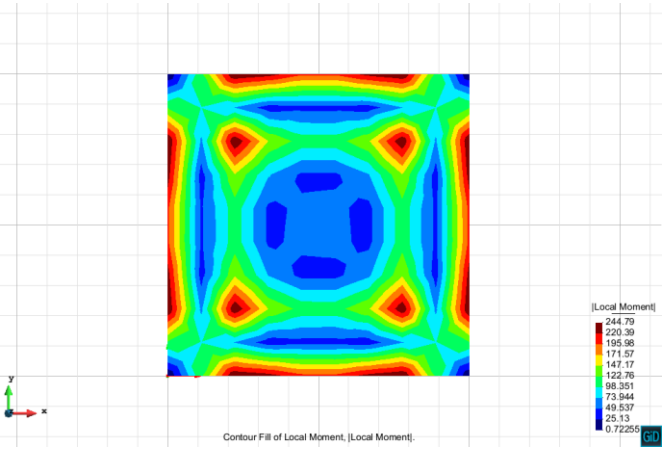

Figure 14. Membrane stress M_{all}

Compared to membrane stresses, the moments are much smaller. This phenomenon proves that the membrane stress is the main stress in shell structures.
The highest moments happen on the boundaries, so we need to reinforce the area where the structure connects the constraints.

(3) Shear stress

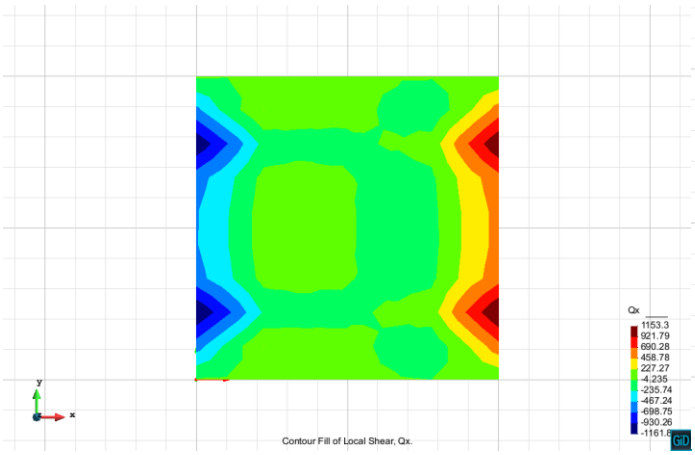

Figure 15. Shear stress Q_x

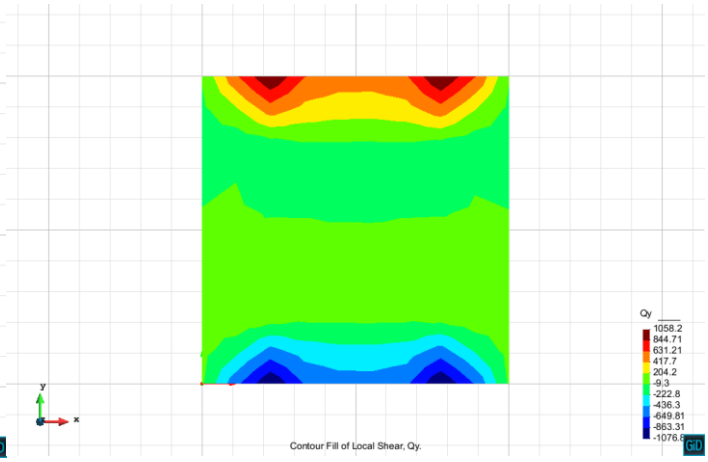

Figure 16. Shear stress Q_y

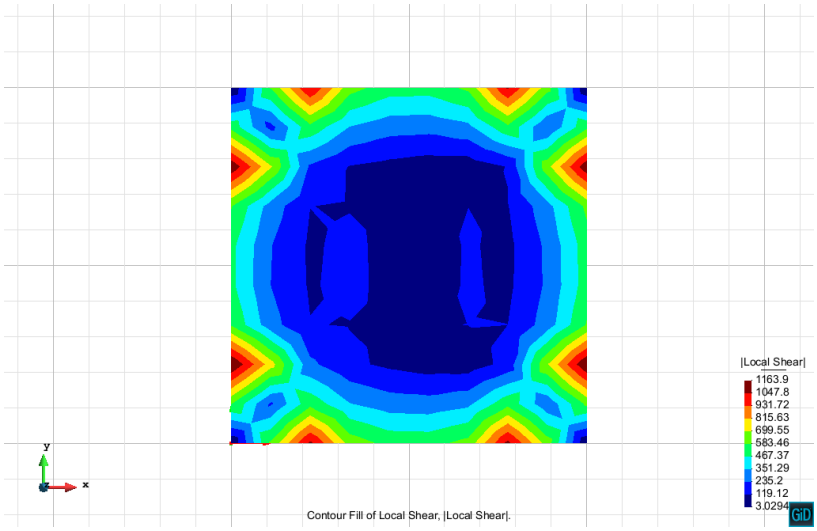

Figure 17. Shear stress Q_{xy}

The highest shear stress also appears on the boundary area like moment stress does. Because shell structures' bear capacity of out of plane is weak, so we need to apply proper means to avoid destructions in these dangerous areas.

⑷ Conclusion

① The corner areas mainly bear the membrane tensile and compressive stress.

② The boundaries mainly bear the bending moments and shear stress. Like arch structures, shell structures have higher requirements for the supports. We need to apply appropriate reinforce measures and materials on these areas so that we can avoid the destructions.

③ The central area mainly bear the membrane shear stress.