CSMD: Assignment 9: Shells

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An hyperbolic paraboloid structure made of concrete (figure 1) and composed of shells has been analyzed using Reissner-Mindlin triangle and QLLL thick-thin shell elements. The structure could be considered as a saddle roof working under its own weight. A convergence analysis of the vertical displacements at the center of the structure has been used to select the adequate element size (see figure 2). The QLLL shows a faster convergence, while the RM triangle shows an initial oscilation. Moreover, for a mesh size equal or larger than 0.5, the RM triangle provides a z-displacement field which only has a local minimum, while for finner meshes there are 4 local minimumns (figure 3). The QLLL provides a similar z-displacement field for all the element sizes tested (figure 3). The properties used for the concrete are depicted in table 1.

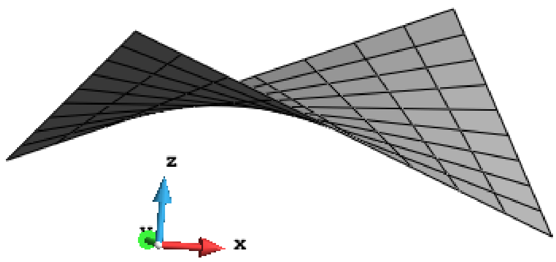
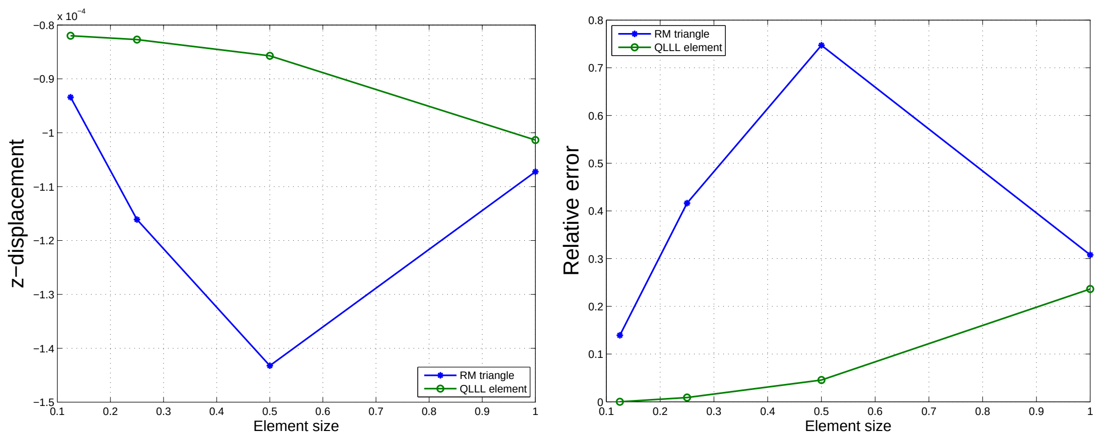


Figure 1: Hyperbolic paraboloid structure

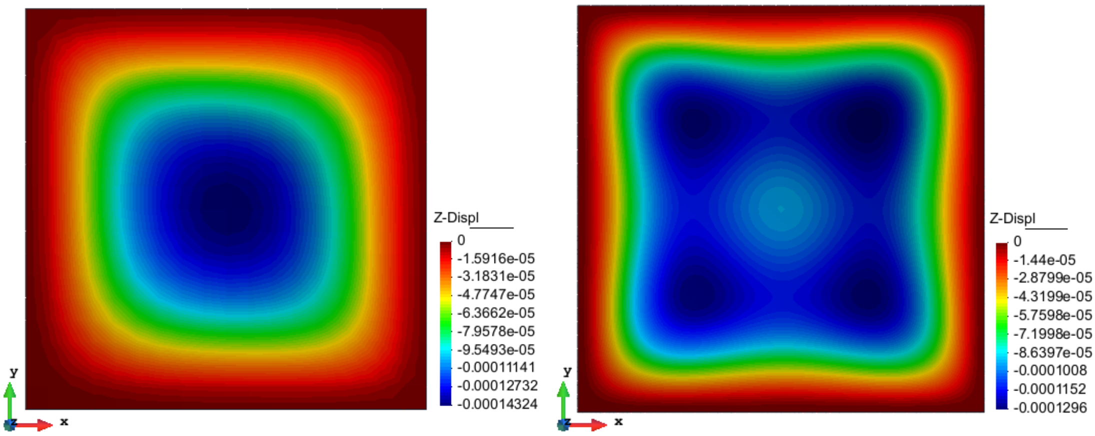


(a) (b)

Figure 2: Convergence study

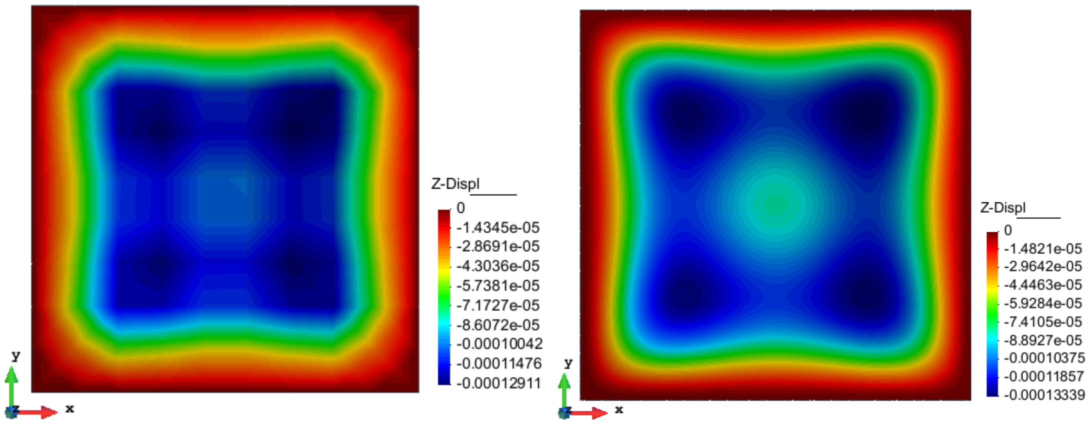
Young Modulus	$3 \cdot 10^{10} \frac{N}{m^2}$
Poisson ratio	0.2
Self-weight	$2500 \frac{N}{m^3}$

Table 1: Properties of the concrete



(a) RM triangle with h=0.5 (b) RM triangle with h=0.5

Figure 3: z-Displacement for different RM triangle meshes.

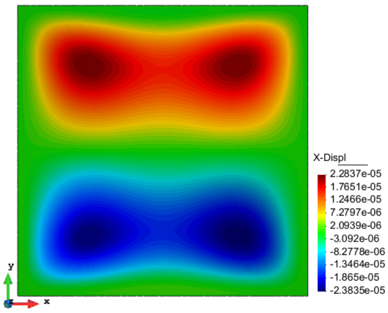


(a) QLLL with h=1 (b) QLLL with h=0.125

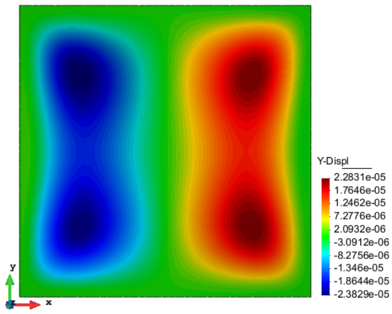
Figure 4: z-Displacement for different QLLL meshes.

The results obtained when using a mesh composed of QLLL thick/thin elements and element size 0.125 are depicted in the figures below. The results obtained are different than if it was a plane plate: The self-weight of the structure produces axial forces and displacements of the middle plane in both x and y directions, and there are four points with minimum displacement, instead than just one on the center. The displacements obtaied show symmetry, and the largest magnitude are in the vertical direction. The dimensions of the displacements are low, so it is correct to use linear elasticy.

The stresses obtained show antisymmetry. The stresses due to bending moments are predominant since it is a thin plate under selfweight. Except for Nxy, the rest of the stresses (N, moments and shear stresses) are important at the edges but vanish at the center of the plate, thus reducing the total amount of stresses at the center, which is very good especially if compared with plane plates. The shear stresses are low since it is a thin plate.

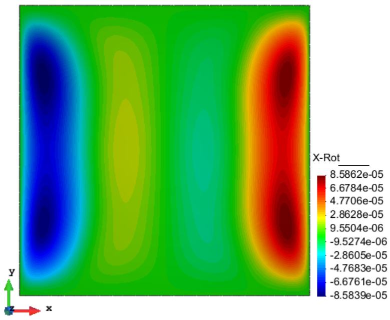


(a) x-displacement

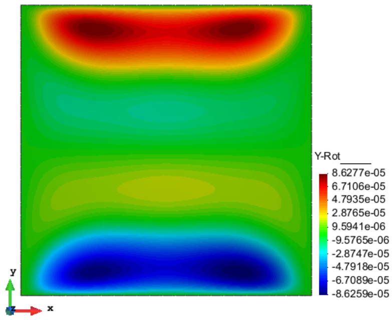


(b) y-displacement

Figure 5: x and y displacements

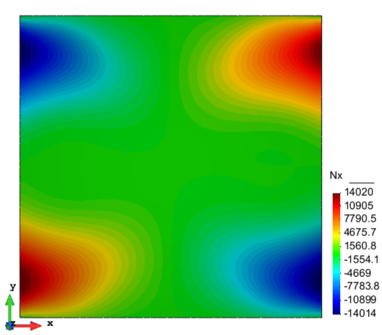


(a) x-rotations

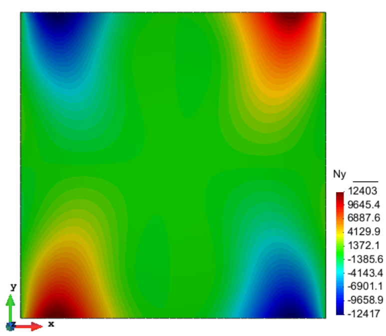


(b) y-rotations

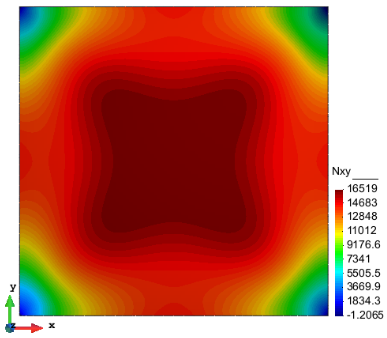
Figure 6: Local rotations



(a) Nx

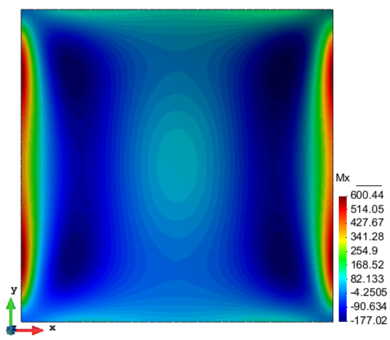


(b) Ny

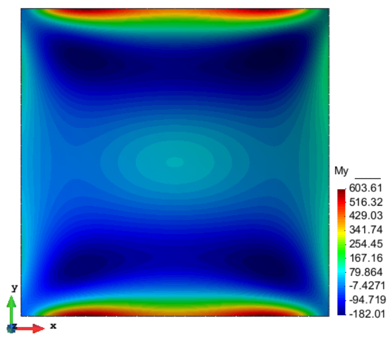


(c) Nxy

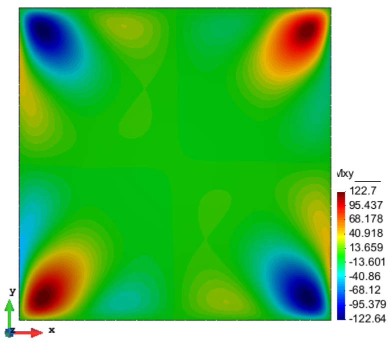
Figure 7: Membrane stresses



(a) Mx

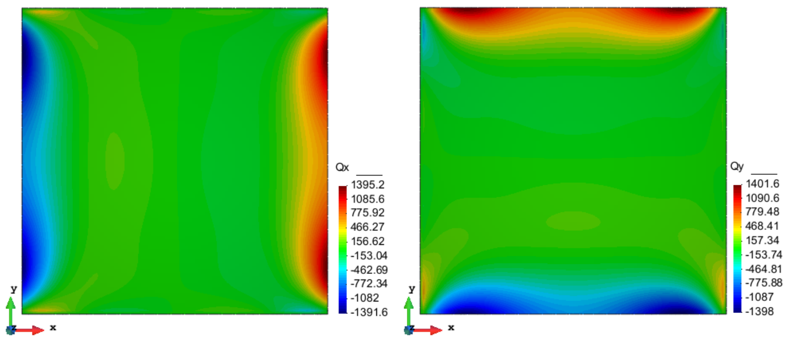


(b) My



(c) Mz

Figure 8: Moments



(a) Qx (b) Qy

Figure 9: Shear forces