Computational Structural Mechanics and Dynamics

Practice 2

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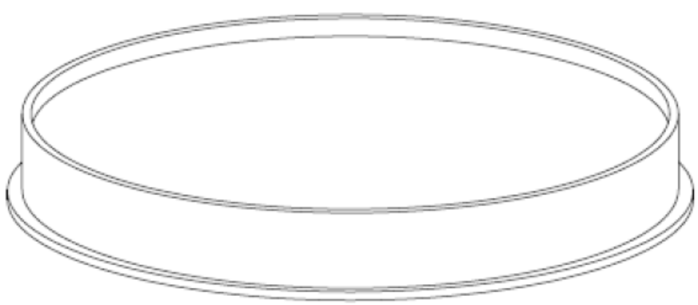
Exercise 1: Circular tank

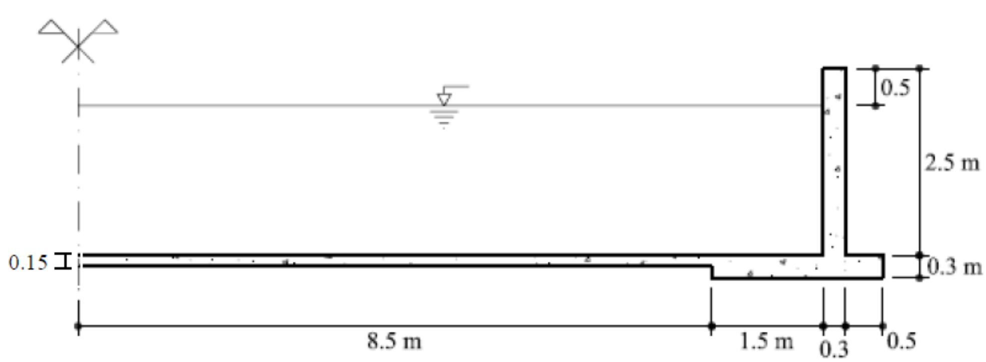
The figure shows a circular tank made of reinforced concrete. It is used for the storage of water in a water purification plant. Analyze the structural behavior of the tank. Use quadrilateral elements with four nodes.

Data

Concrete $\begin{cases} E = 3.0e10 \ \dfrac{N}{m^2} \\ \nu = 0.2 \end{cases}$

Floor $\left\{ \text{Ballast coefficient} = 50 \dfrac{N}{cm^3} \right.$





Solution:

The tank is modelled using the fact that it is symmetric around the y axis. Internal loads are liquid pressure (hydrostatic, meaning constant at the bottom of the tank, linear increasing on the side)

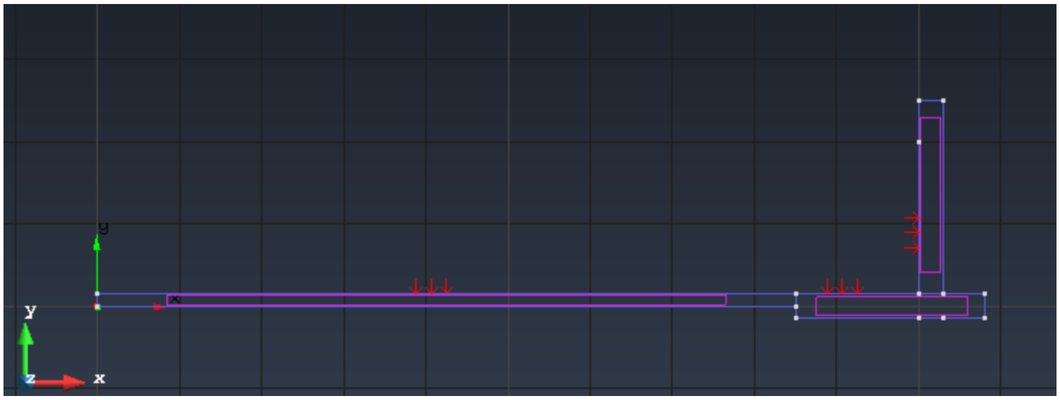


Figure 1 Geometry and internal loads

Support on the base of the tank is modelled using a linear elastic constraint as per the ballast coefficient provided.

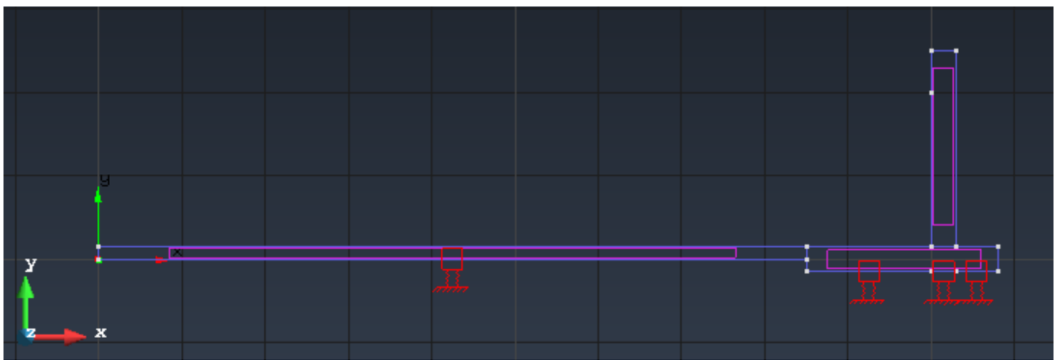


Figure 2 Linear elastic constrains applied at the base of the tank

The gridding was done using square elements as shown below

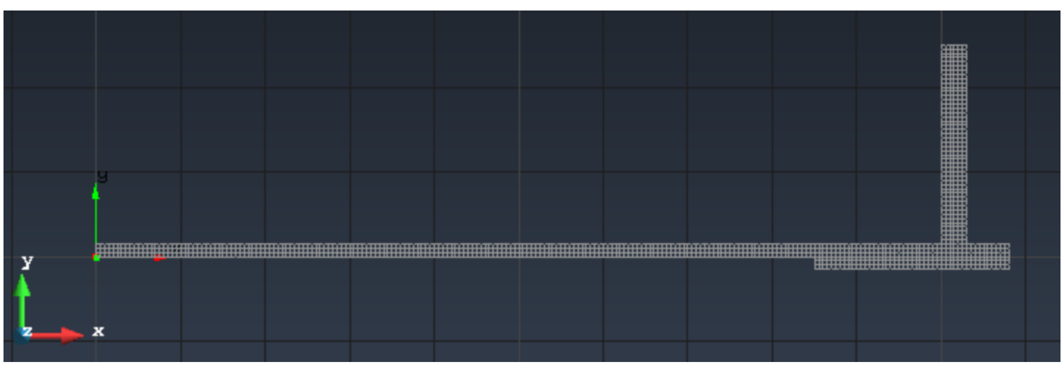


Figure 3 Mesh of quads, 5cmx5cm. Num. of Quadrilateral elements=1.068 Num. of nodes=1.338

Largest stresses in the x direction (radial in this case) seem to occur at the bottom of the tank (on its base). The wall is being pushed outwards by the fluid inside, and the base has to compensate this with large compression.

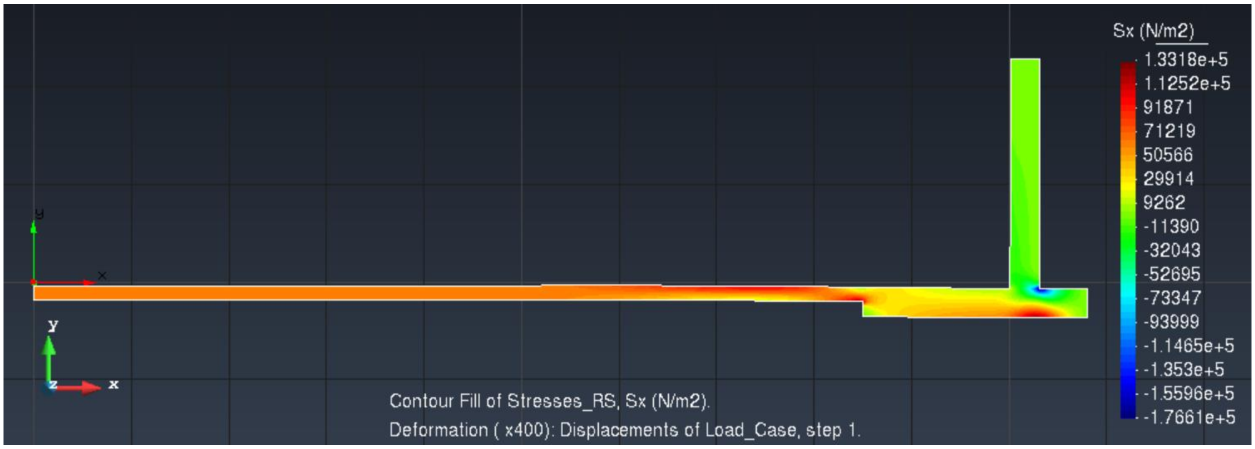


Figure 4   stresses in the x direction (in this case, radial stresses)

The outer wall is being stretched by the y stresses whiles the inner wall is being compressed.

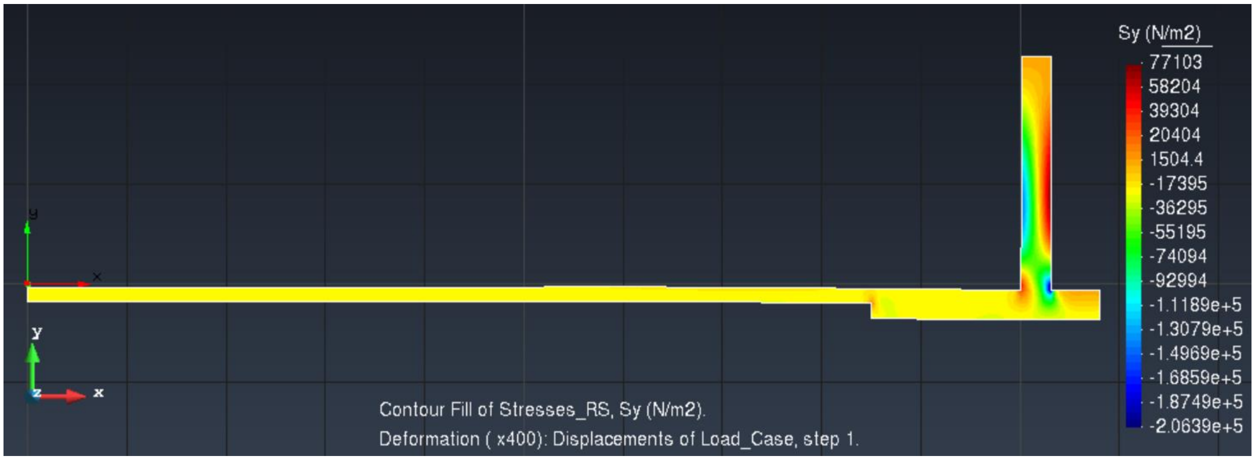


Figure 5   stresses in the y direction

In the theta direction, stresses are maximum on the wall, especially on the outside, as the fluid pushing from the inside stretched the wall.

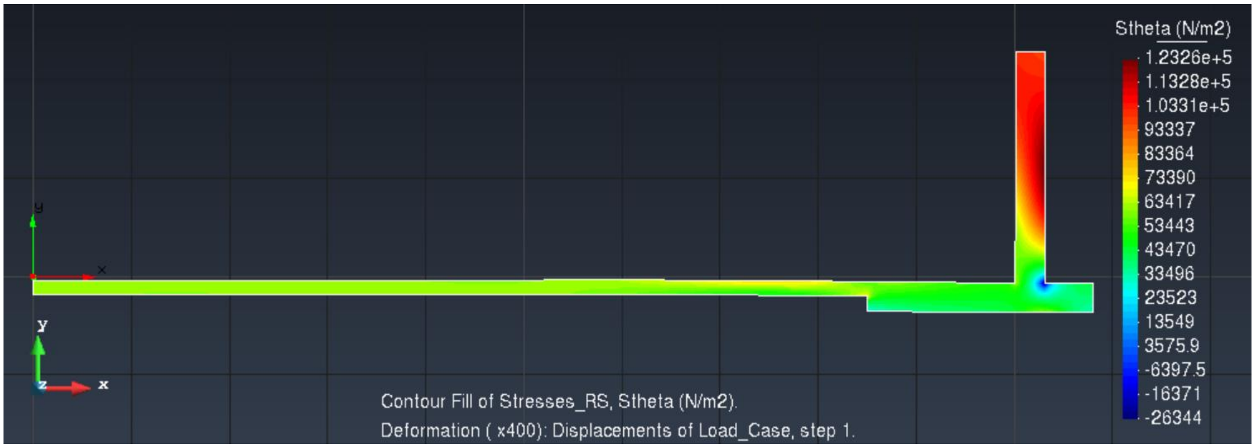


Figure 6 theta-direction stresses (tangential)

Final shape and magnitude of displacements are shown below. The outer side of the tank is being pushed outwards and downwards by the action of the fluid.

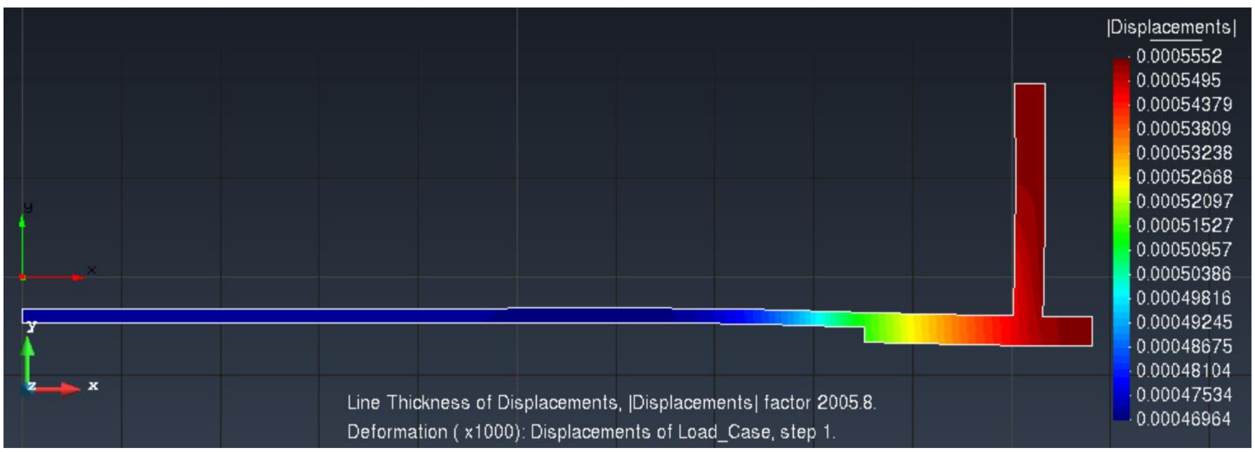


Figure 7 1000x displacemects

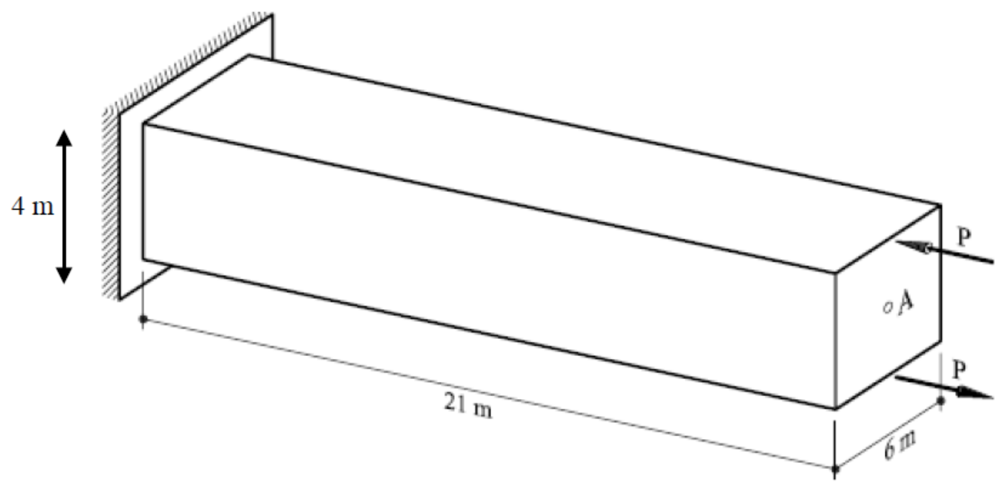
Exercise 2: Analysis of the flexion of a beam using hexahedra elements.

Analyze the cantilever shown in the figure, submitted to the action of a moment at the far end. Compare the results obtained with the beam theory. Use hexahedra elements with 8 and 20 nodes.

Data

$$\text{Material}\begin{cases} E = 2.1e11\dfrac{N}{m^2} \\ \nu = 0.20 \end{cases}$$

$$P = 10000N$$



Solution:

The cantilever was modelled using cubes. The mesh size was is 1mx1mx1m which resulted in almost 2000 elements. The loads where applied as point loads as indicated in the figure

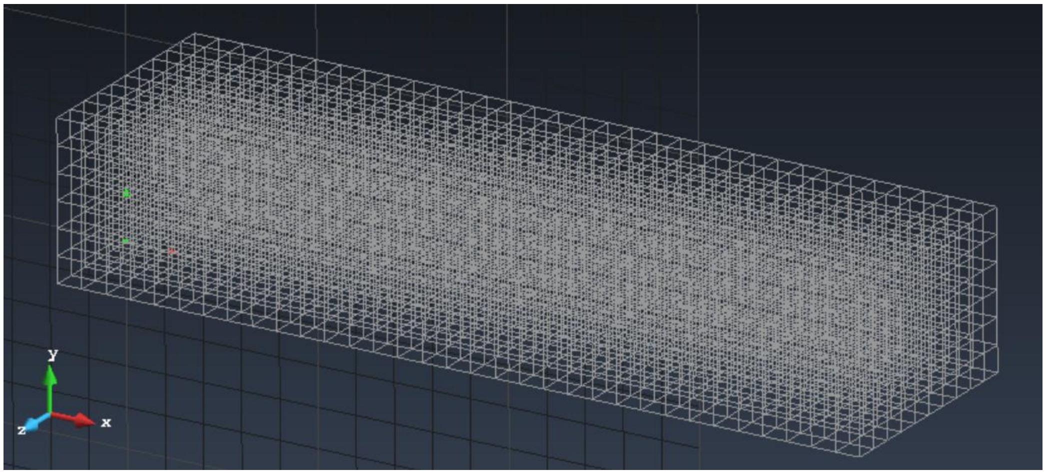


Figure 8 cubic elements, 1mx1mx1m in size Num. of Hexahedra elements=1.980, Num. of nodes=2.618

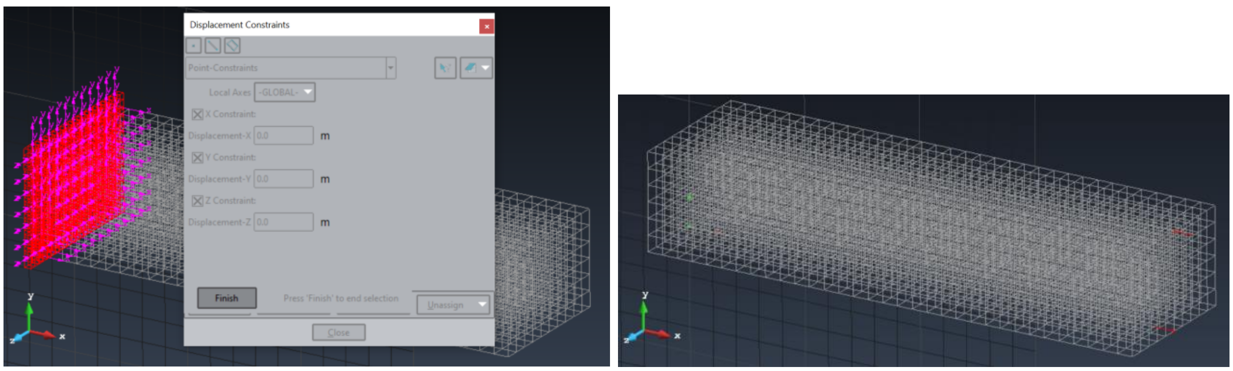


Figure 9 problem data, displacement constraint of zero in X and Y where the cantilever attaches to the support (left) and point forces applied on the opposing faces (right, small red arrows)

As would be expected, the point loads cause extreme displacements were they are applied and have much smaller impact in the rest of the structure.

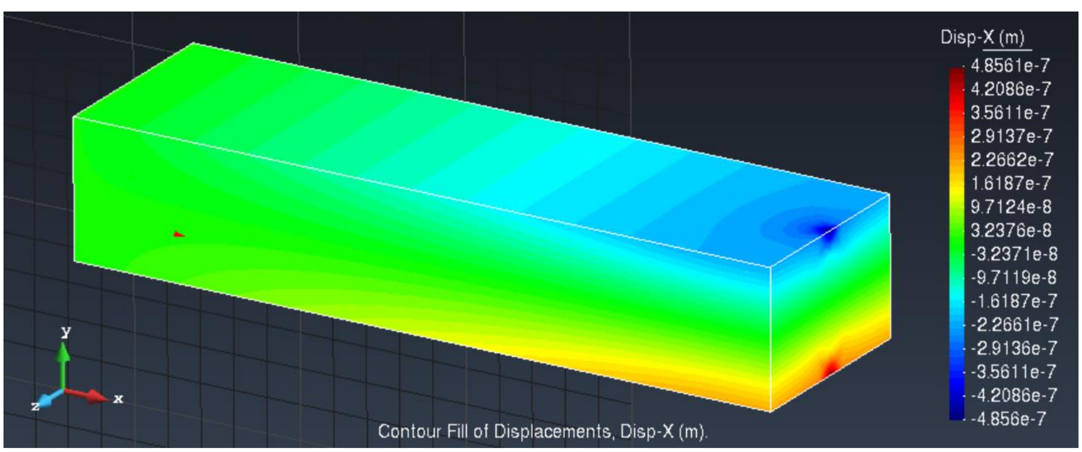


Figure 10 X direction displacements

Positive vertical displacement is experience by the cantilever as shown in the next two difures

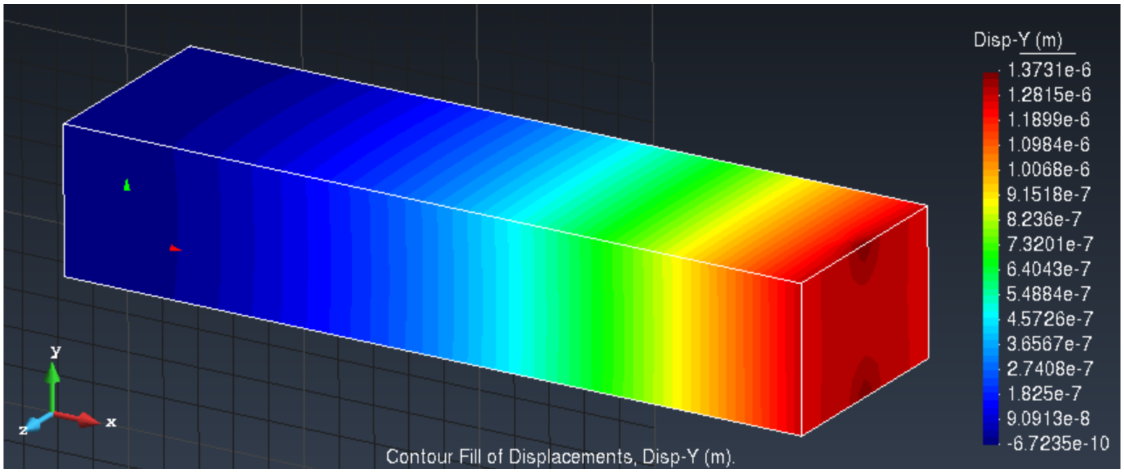


Figure 11 Y direction displacements

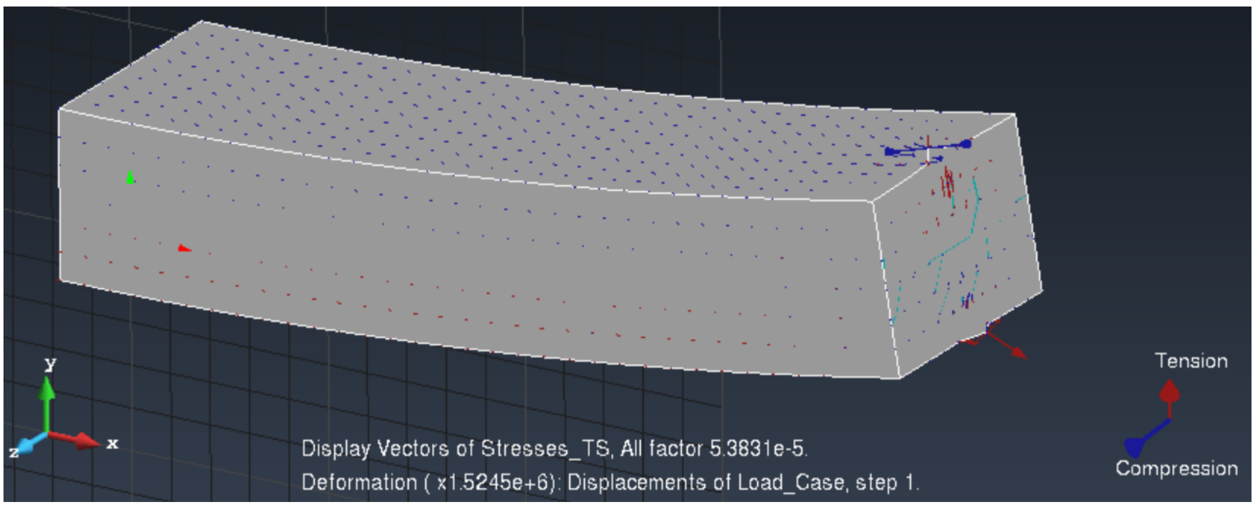


Figure 12 stress vectors plus final shape (exaggerated) of the cantilever

A second simulation was run on the same mesh, run with 20-node elements

The increase in run time was greater and 10x. The results are shown below. Essentially the simulation indicates all the same effects occurring. Compared with the lower resolution model (8 nodes per element) the high-resolution model (20-node elements) shows more extreme values of displacement and stress for the places where the point loads are exerted. This is the only location where it is work increasing the resolution. The other locations show practically identical behavior of displacement and stress.

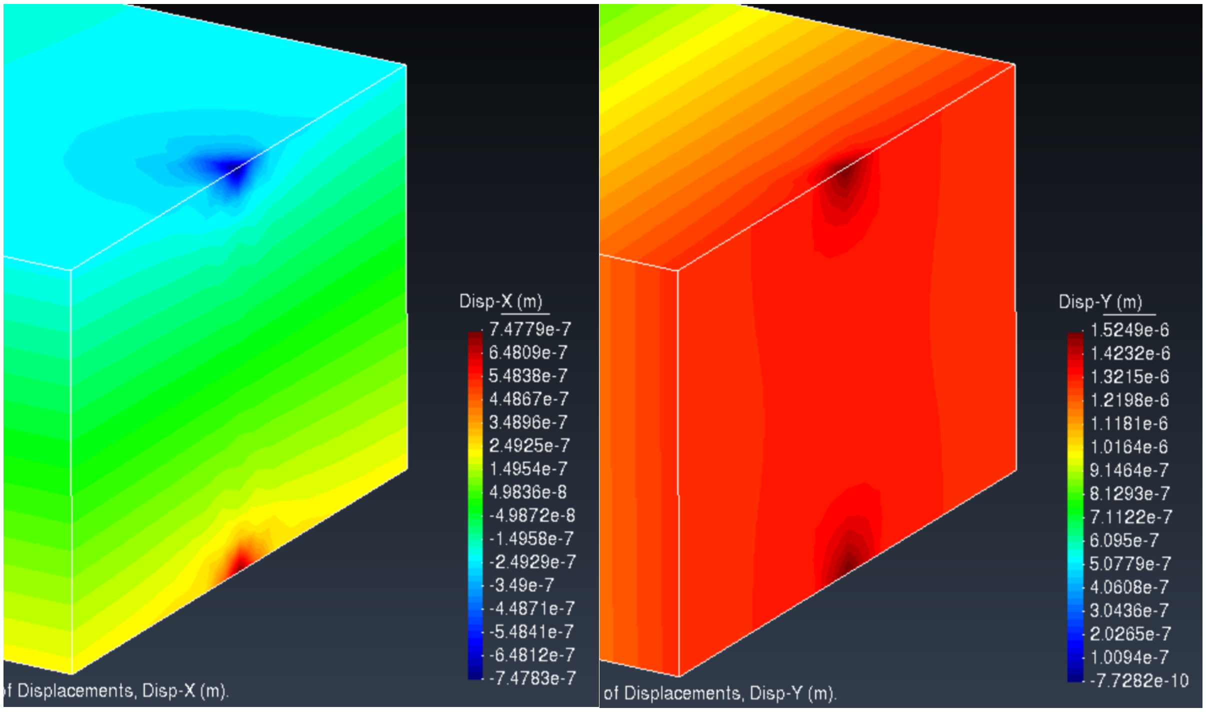


Figure 13   detail of high resolution model displacements. 20 nodes per element.

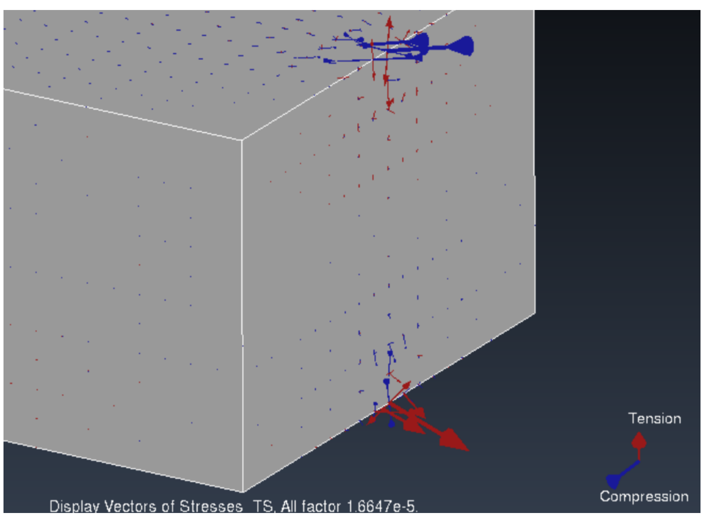


Figure 14   location where the point loads are applied. The only place were higher order elements are justified.

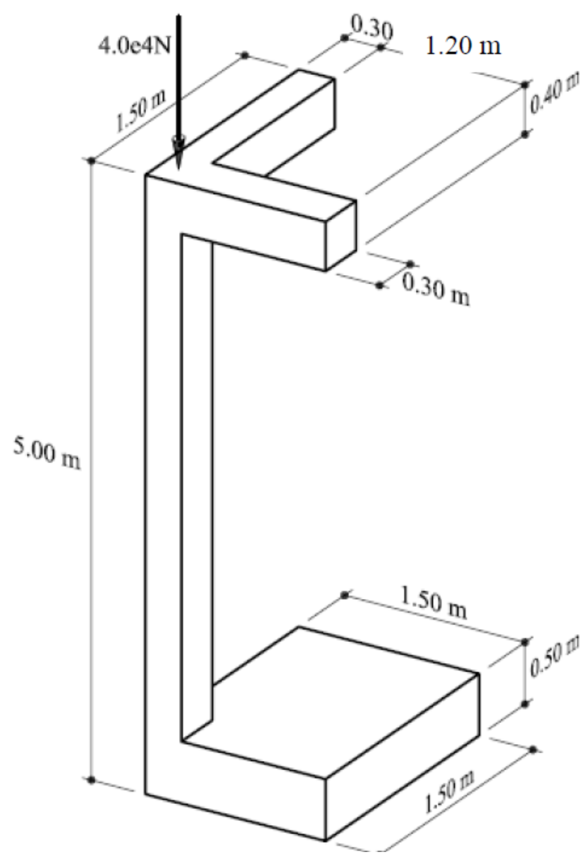
Exercise 3: Foundation of a corner column.

The figure shows a corner column with its foundation. This type of foundation is characterized by the fact that the support reactions are eccentric with respect to the load of the column. This results in a flexion of the column and lifting of the base slab. Analyze the state of stress in the column and the slab under the assumption that the slab is supported elastically by the ground. Determine whether or not the slab suffers lifting. Use hexahedrons with eight nodes.

Data

Concrete $\begin{cases} E = 3.0e10 \ \dfrac{N}{m^2} \\ \nu = 0.2 \end{cases}$

Ground $\left\{ \text{Ballast coefficient} = 50 \dfrac{N}{cm^3} \right.$



Solution

The geometry was uploaded to GID and a mesh of cubes generates. Three types of boundary conditions were applied: zero displacements on the faces of the cantilevers, vertical load on the top of the column and an elastic constrain applied at the bottom of the foundation.

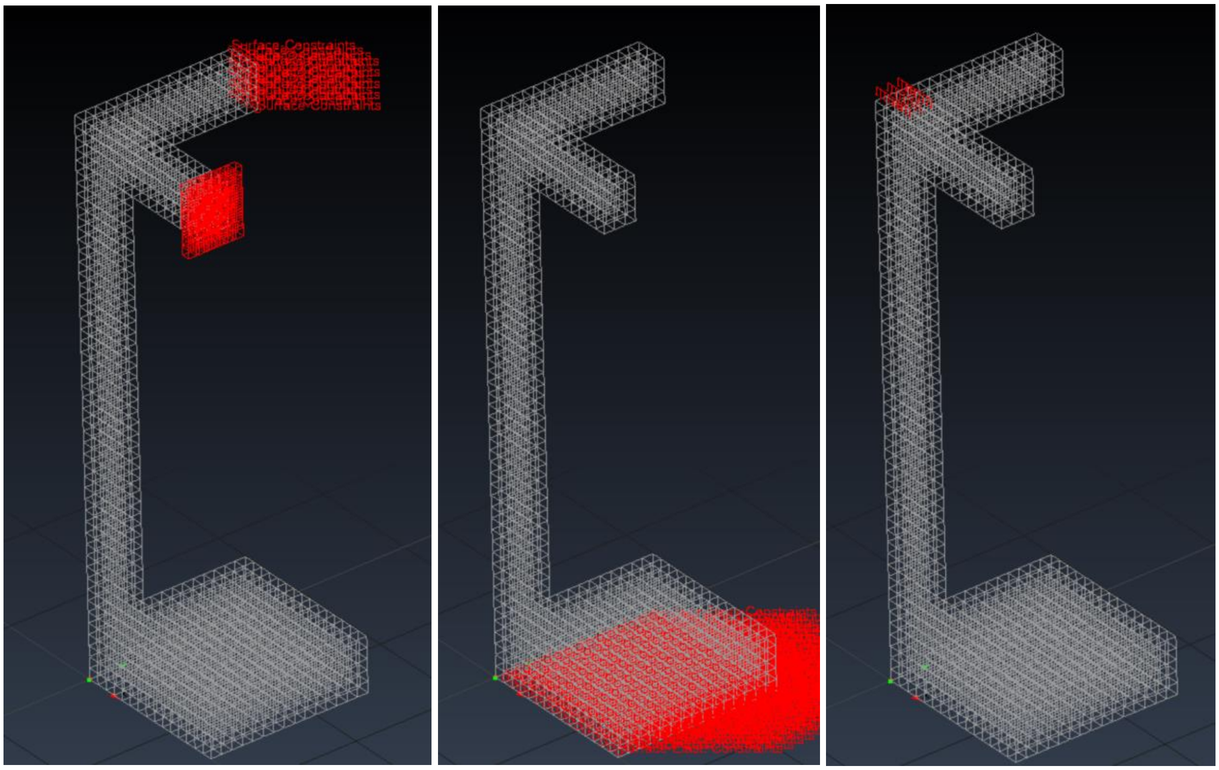


Figure 15 left: zero displacement constraint applied on faces (assumes the column is part of a symmetric structure), Center: elastic constraint applied at the bottom as per ballast coefficient. Right: distributed load applied top the column.

The simulation was carried out using 3D solids an the results are shown below.

Notice that the foundation experiences asymmetric load. The ground subsides on the side od the foundation attached to the column. On the other hand, the opposite corner of the foundation experiences upwards lift. Also, the foundations experiences displacement towards the corner opposite of where the column is attached (fig 17). As expected from the displacements, the z stresses are compressive on the side of the foundation and extensive on the opposite side.

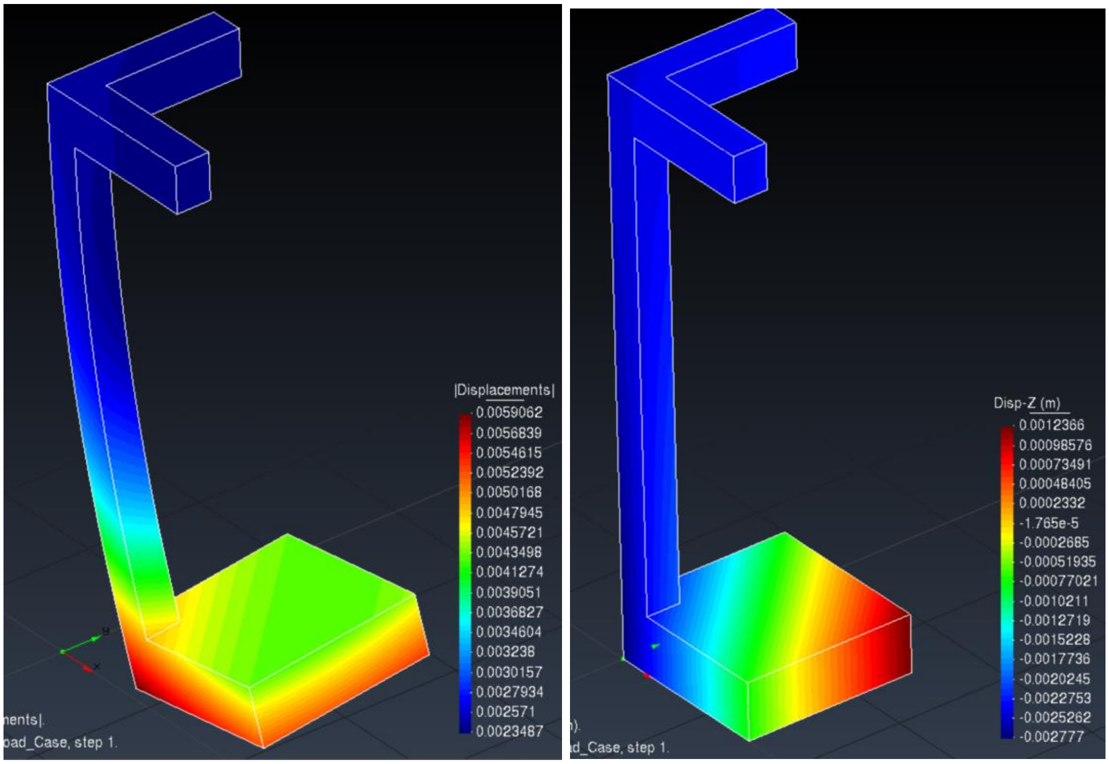


Figure 16 displacements. On the left, final shape of the column and its foundation. On the right, vertical displacement

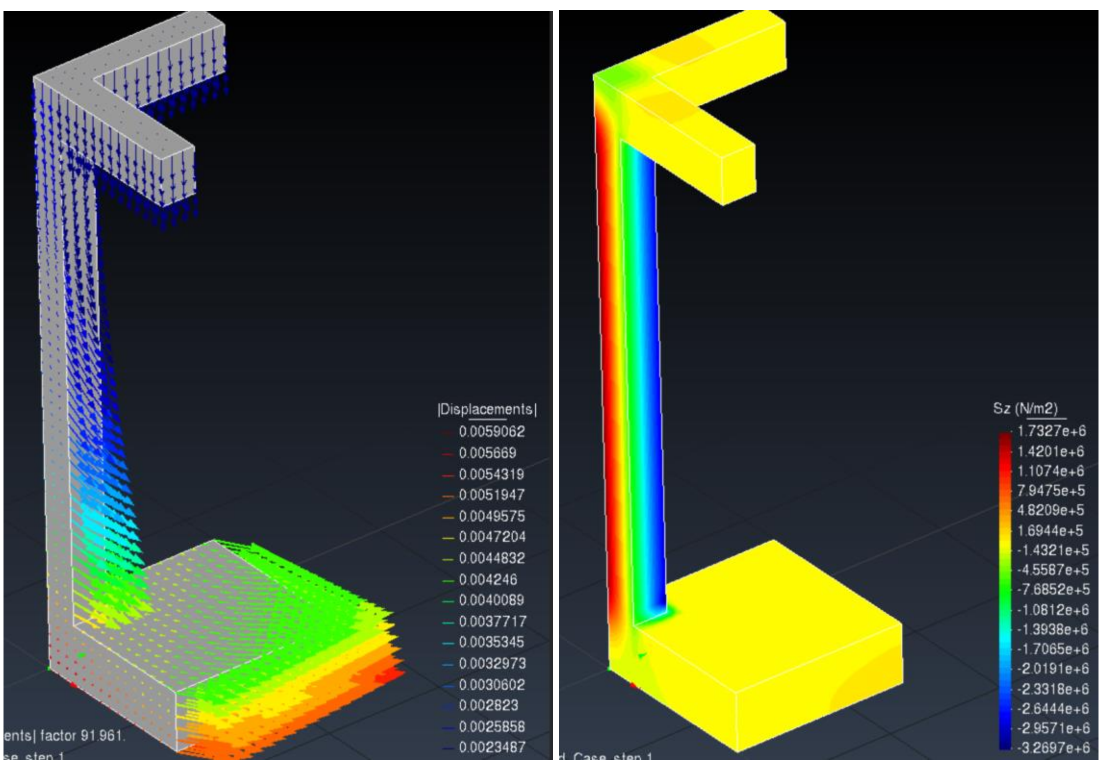


Figure 17 on the left the displacement vectors, on the right the stresses in the z direction