Master on Numerical Methods in Engineering

Computational Structural Mechanics and Dynamics

Practice 2

GiD and RamSeries module

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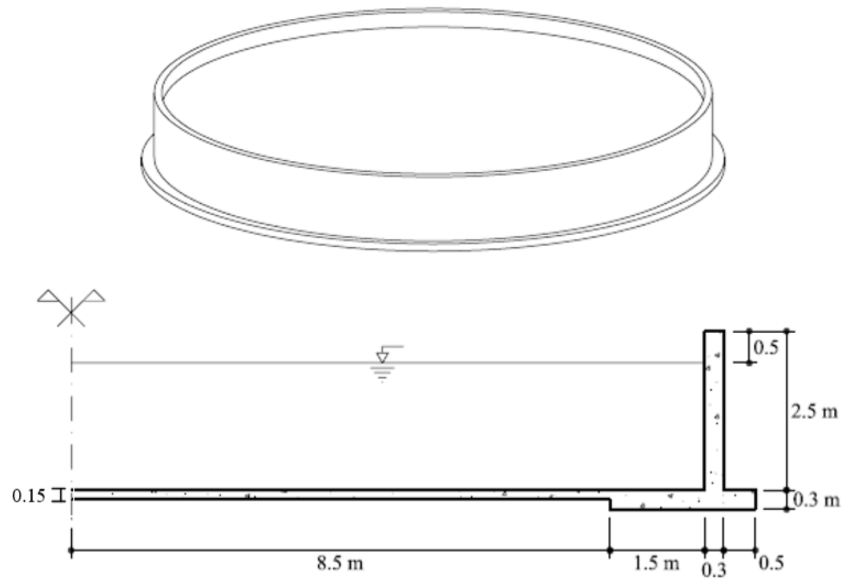
Exercise 1: Circular tank

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

Data

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

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



Structural behaviour has been solved with the use of plane strain theory. In order to ease and reduce computational cost, symmetric geometric and load distribution properties were applied.

In order to analyse the structural behaviour, it was needed to compare the effects that self-weight have on the behaviour with respect to a model when self-weight is neglected.

<u>Problem conditions were set as follow</u>:

- Static loads (Figure 1):

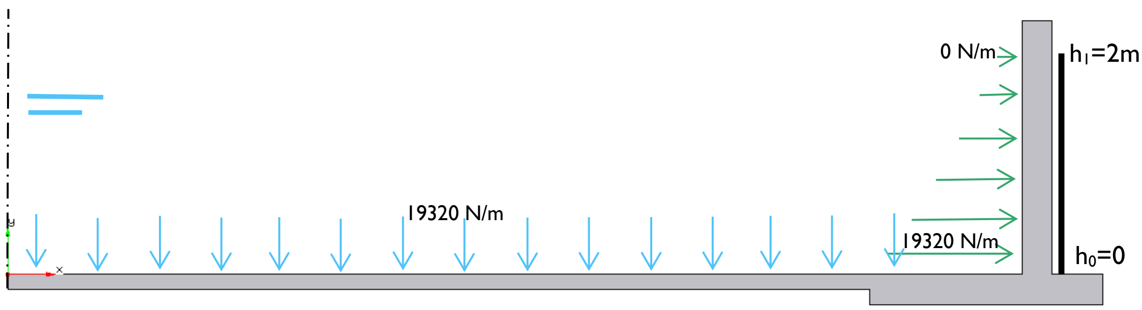


Figure 1. Static loads related to water pressure

- Uniform distributed load along line 1 (19320 N/m).
- Linear static load against wall as a static pressure ($\varphi_w * g * h$) where

$$h_0 = 0 \; and \; h_1 = 2m.$$

$$1000 * 9.81 * 2 = 19320 \text{ N/m}$$

- Displacement constraints:
  $u_x = 0$ and $u_y = 0$ displacement constraints in y=0 due to symmetry reasons

- Elastic constrains as problem definition: Floor ballast coefficient is 5E7 N/m^3

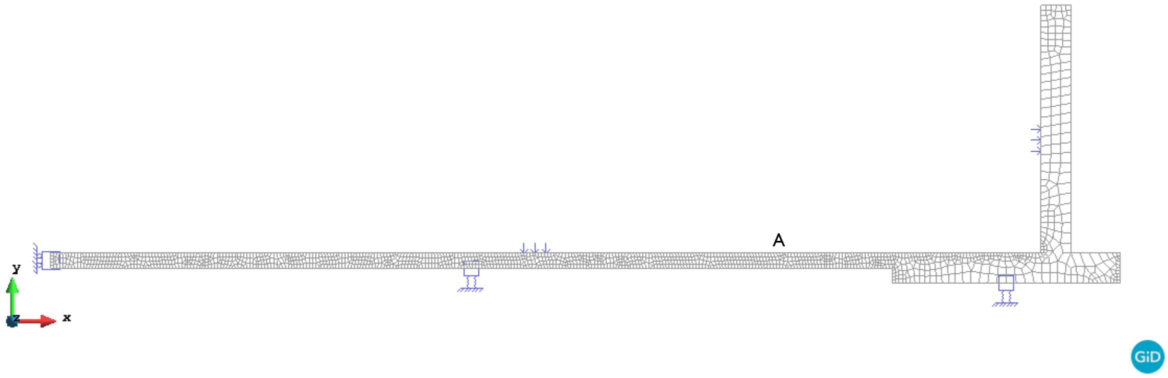
Mesh definition:

Table 1 contains the mesh analysis comparison between 5 alternatives for the quadrilateral 4-noded element unstructured mesh:

Mesh	Element size	Elements	Nodes	Ux	Uy
I	0.1	754	999	4.5005e-5	-2.373e-4
II	0.05	1084	1357	4.5399e-5	-2.551e-4
III	0.1	1862	1484	4.5224e-5	-2.544e-4
IV	0.05	1942	2352	4.5224e-5	-2.544e-4
V	0.03	2991	3444	4.556E-5	-2.555e-4

Table 1. Mesh description. Sensitive analysis.

Case III (Figure 2) was taken as the most appropriate mesh for the analysis. Results are shown for this case.



In the case of self-weight neglected, deformations cause the contraction of the structure. In other words, pressure is high enough to cause that the wall moves towards the symmetric y-axis. Static load is mainly affecting slab. Soil absorbs exected pressure effect. As it was expected, values are lower in self-weight neglected case. Point A is the inflection point so, when considering self-weight, wall and foundation substructure start mainly working in under traction so that, deformation wall is outsider. At the wall inside is submitted to contration (magnitude values change) while outside wall is mainly suubmitted to compression.

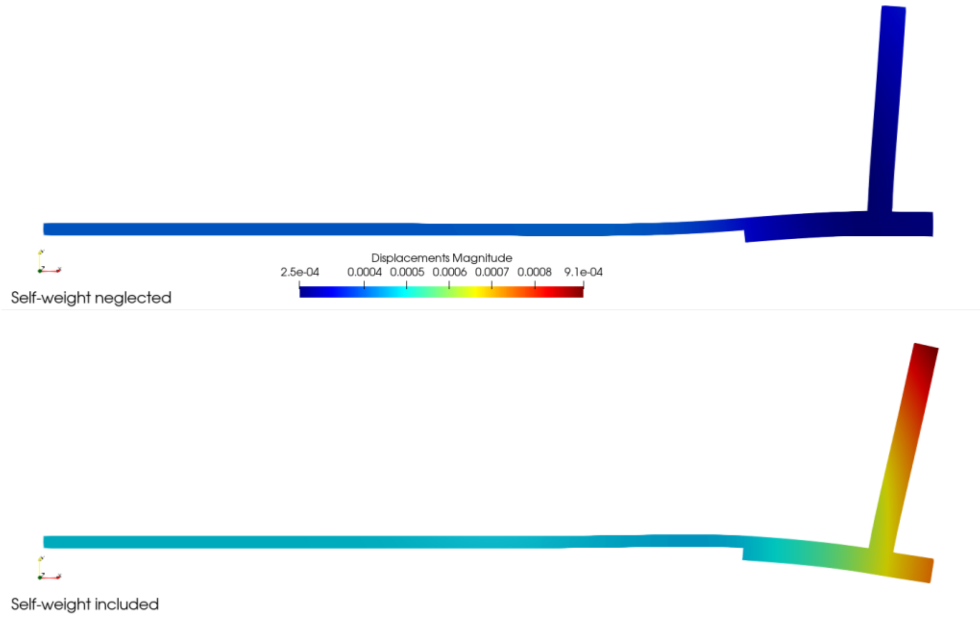


Figure 3. Magnitude displacements. Self-weight neglected in comparison with self-weight included when the other conditions are the same.

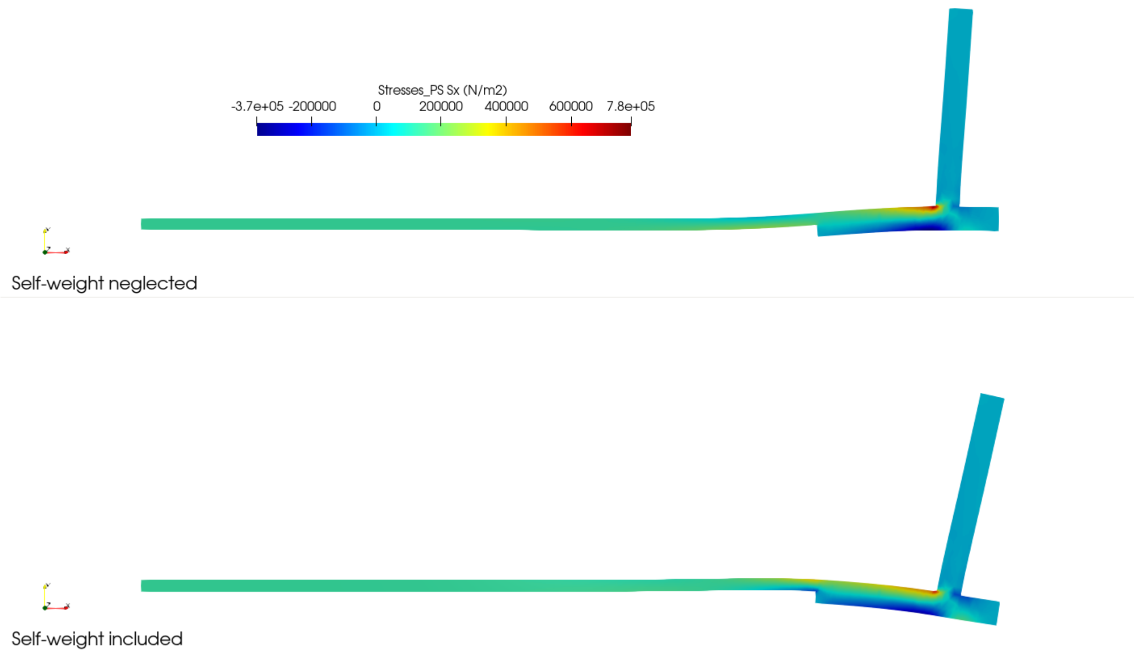


Figure 4. σ_x $results$. Self-weight neglected in comparison with self-weight included when the other conditions are the same.

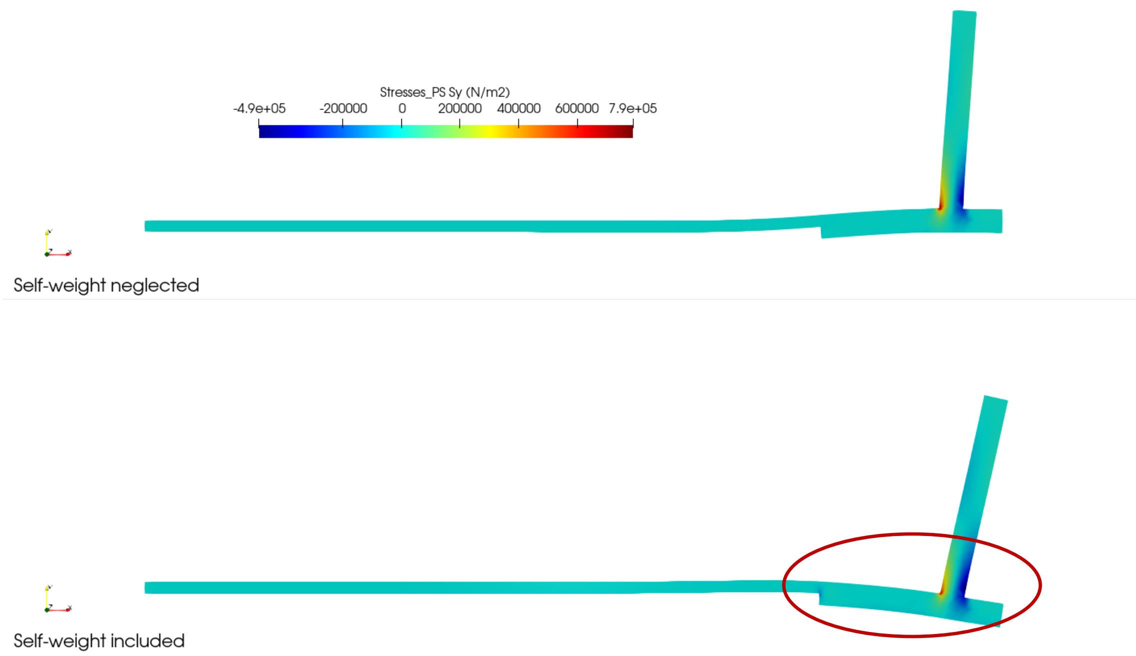


Figure 5. σ_y $results$. Self-weight neglected in comparison with self-weight included when the other conditions are the same.

Cualitatively, stresses are equivalent values for both cases. It is notewhorthy that from point A to the right, stress magnitude is bigger when body weight is considered.

The problem was pre-processed in the FEM software GiD while the used solver is RamSeries Educational 2D→Plane strain theory. Post-process was done on Paraview software (given a variable to compare, legend values are shared for both figures).

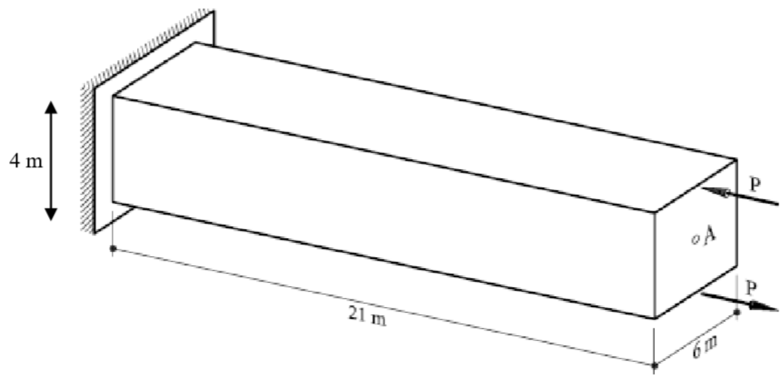
Exercise II Analysis of the flexion of a beam using hexahedra elements

Analyse 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

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

$P = 10000N$



Analytical values. Beam theory:

Vertical displacement for the given value is calculated by Equation 1:

$$\delta_y = \frac{M*L^2}{2*EI} \qquad [1]$$

Where

$$E*I = 2.1e11 * \frac{6*4^3}{12} = 6.72e12$$

$$M = 10000*2 = 20000\ Nm$$

This yields to:

$$\delta_y = 6.56\ e-7\ m$$

Numerical approach:

Several options were tested in order to find the most appropriate modelling conditions settings. Some alternatives were:

a) Load→Surface load→Global projected pressure
b) Load→Surface load→Uniform pressure
c) Load→Surface load→Trapezoidal pressure
d) Load→point load

It was selected the c) option. Load was linearly distributed along the cross-section; it takes 0 value at the point A. Simulation conditions are defined in figure 1.

Figure 1. Momentum force at the far end

According to problem description, it must be used 8 and 20-noded hexahedrone elements. It order to use this element type, volume entity was defined as for a structured mesh. Element sized were tested for: 0.5, 1 and mesh refinement of the combination of both.

Mesh refinement was described in Figure 2.a and coarser mesh is presented in Figure 2.b:

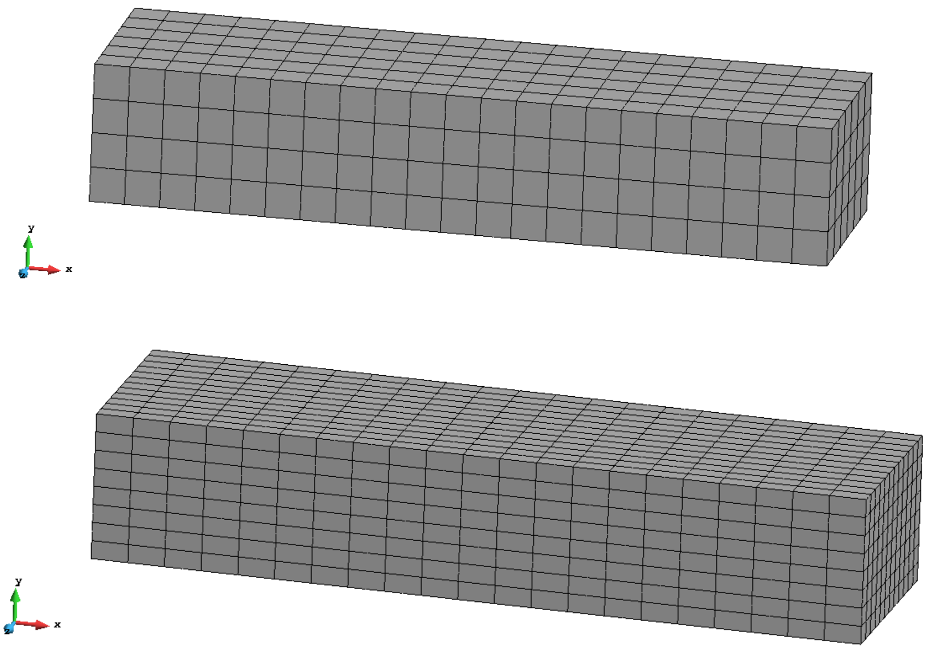


Figure 2. Mesh description. 8 and 20-noded hexahedrone elements

Results:

Table 1 compares y-displacement value at point A.

			Element	Nodes	Y-displacement
	Case	Analytical value			6.560E-07
Coarse mesh	1	8-noded element	504	770	5.098E-07
	2	20-noded element	504	5031	5.230E-07
Refined mesh	3	8-noded element	2016	2574	5.939E-07
	4	**20-noded element**	**2016**	**9695**	**6.106E-07**

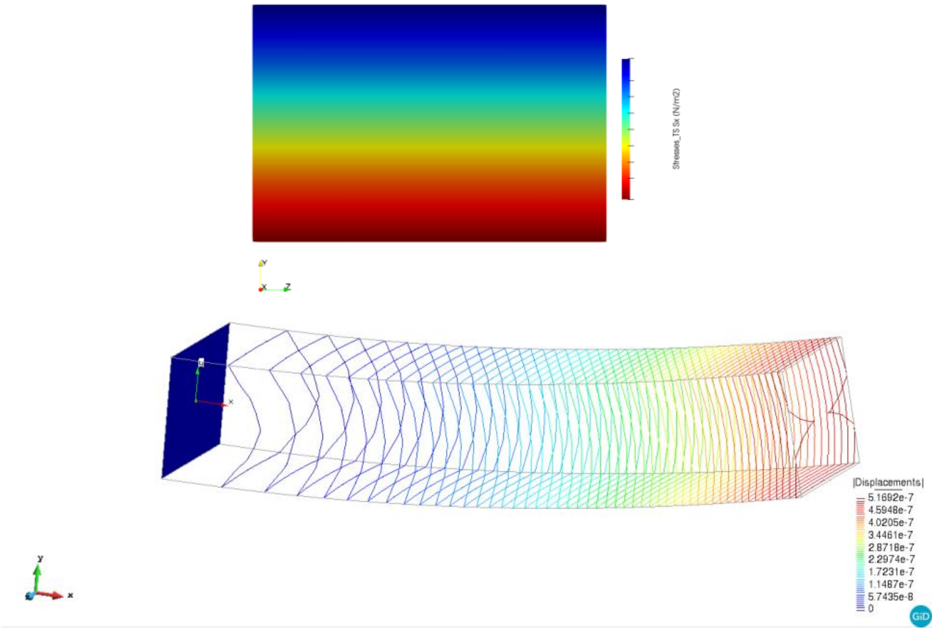
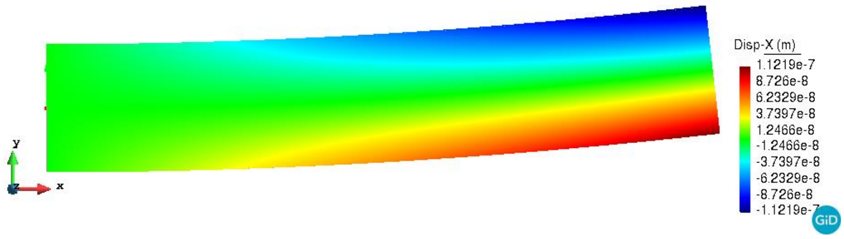
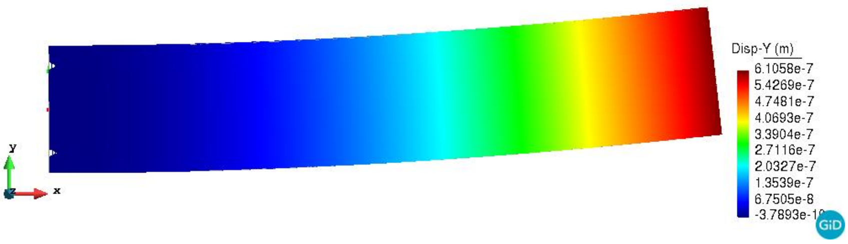
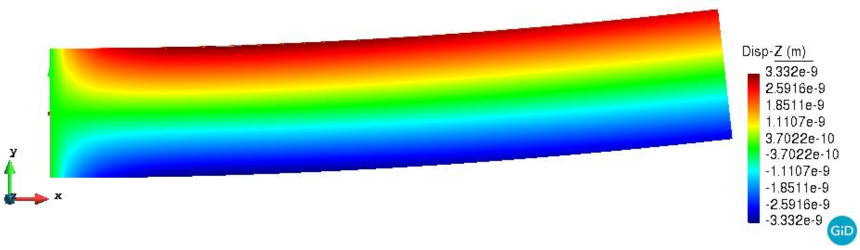


Figure 3. Axial stress distribution at plane YZ, at point A when x=21 (Contour fill filter)







More simulations could be done to get closer to the analytical vertical displacement value. However, they are considered enough to fulfil the problem description requirements. It is concluded that Case 4 is the best alternative.

The problem was pre-processed in the FEM software GiDHOME while the used solver is RamSeries Educational 2D→3D solids. Post-process was done on Paraview software.

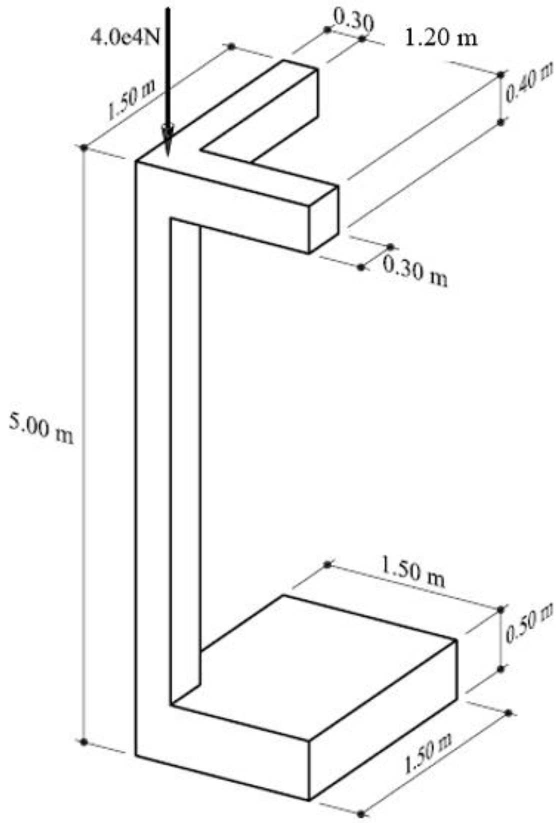
Exercise III: Foundation of a corner column

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



Geometry and mesh definition

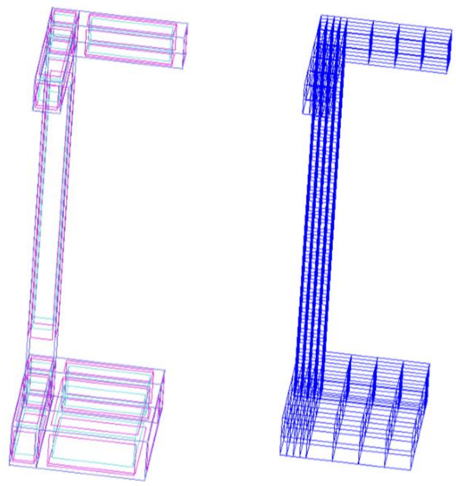


Figure 1. Geometry (l.h.s) and mesh (r.h.s) definition

Simulation conditions:

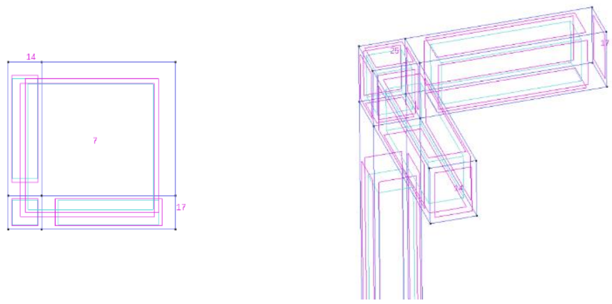


Figure 2. Surfaces where boundary conditions were defined

- Surface 14 is constraint in x-direction
- Surface 14 is constraint in y-direction
- Surface 7 is constraint to ballast coefficient
- 4e4 N load is assigned to surface 25
- Material properties are applied as defined in the exercise description

Results:

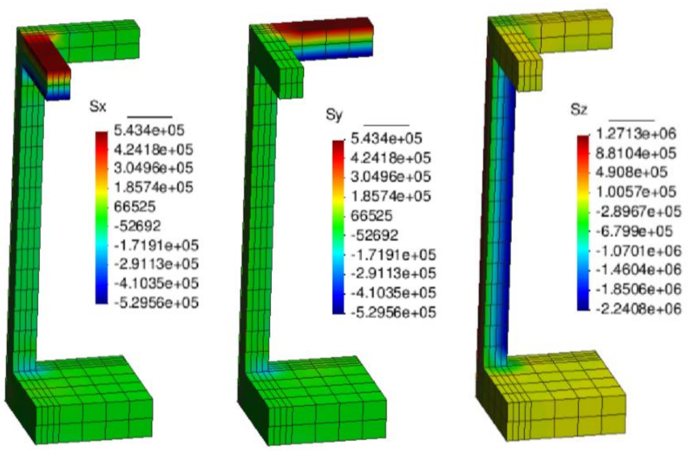


Figure 3. X, Y and Z stresses

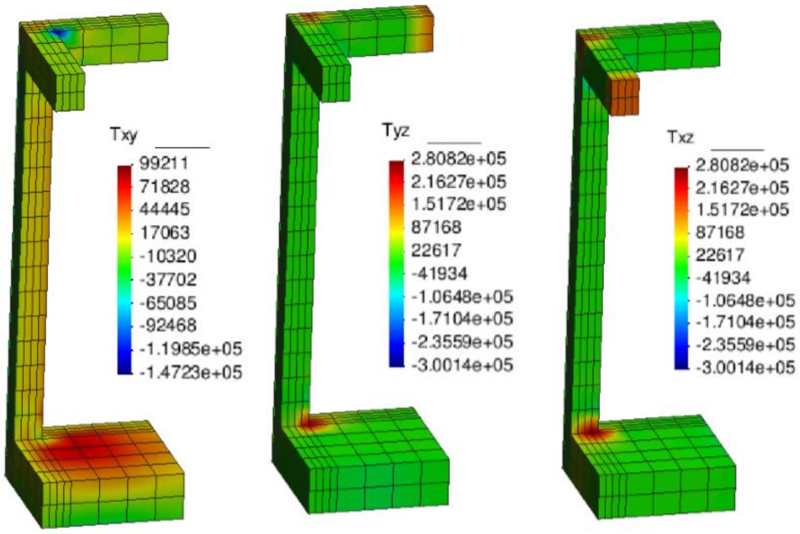


Figure 4. XY, YZ and XZ stresses

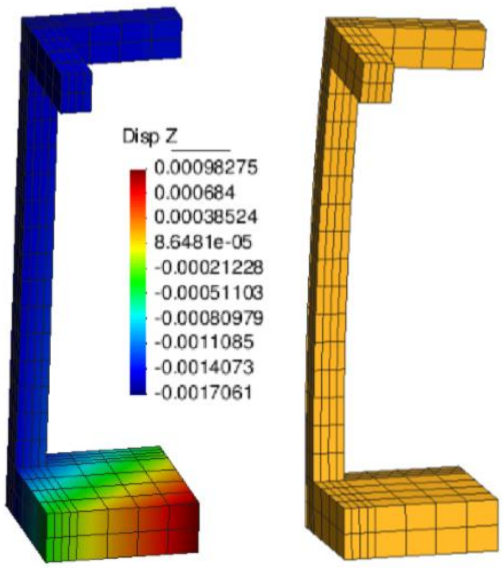


Figure 5. Z displacement and structure deformation