NTNU – NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF ENGINEERING
DEPARTMENT OF STRUCTURAL ENGINEERING

TKT4142 Finite Element Methods in Structural Engineering

CASE STUDY 5

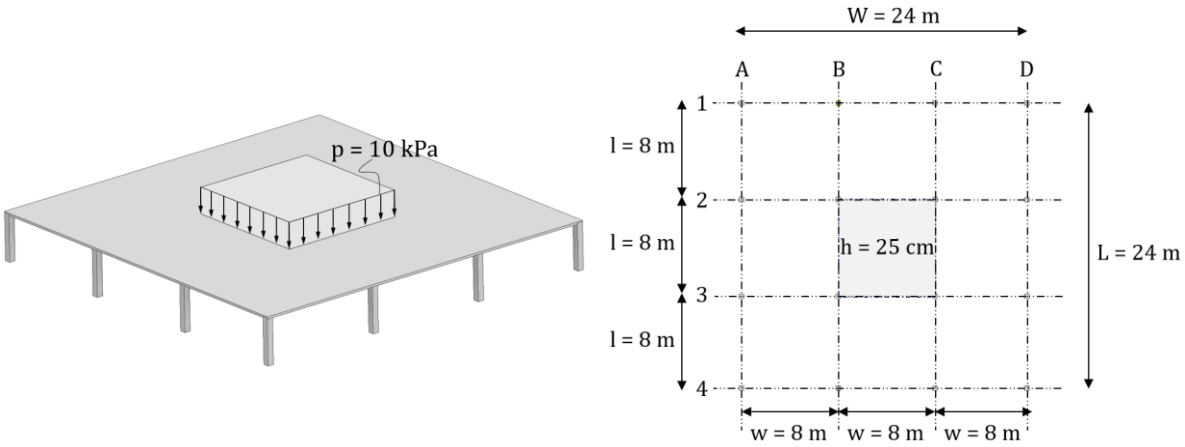
Case Study 5 will use a concrete slab to address the modelling of plate problems. Slabs are plane structures and plate elements are representative of pure bending problems. In plate problems, the thickness t is small compared to its other length dimensions L (e.g., $1/10 < h/L < 1/3$). A workshop on how to model the different aspects addressed in this case study is uploaded to Blackboard (see "*Workshop5.pdf*" in the folder "Case studies"). In Task 1, we will start by modeling a slab with uniformly distributed loading before representing this uniform loading as several point loads distributed over the surface area of the slab in Task 2.

Learning outcome:

- Modelling of plate problems
- Convergence studies
- Visualization and post-processing of results in Abaqus/CAE

Problem description

Figure 1 shows the rooftop of a car park. The rooftop is to be considered as a concrete slab with thickness h = 25 cm. The entire rooftop should be evaluated for a load case where the part of the rooftop between axes B, C, 2, and 3 is loaded with a total weight of 6 cars (including passengers). The loaded area is illustrated as the shaded area in Figure 1b. Assume that the rooftop is supported by the columns in the vertical direction. Also assume that the slab is loaded by a uniformly distributed pressure (p) of 10 kPa on the top surface. The material properties correspond to a concrete of class B30. Assume that the concrete material remains uncracked during deformation.



(a) (b)

Figure 1 – A rooftop supported by 16 columns and exposed to a uniform load p = 10 kPa between axes B, C, 2, and 3.

Load: $p = -0.010\ \text{N/mm}^2$ (downwards)
Material data: $E = 32\,000\ \text{N/mm}^2$, $\nu = 0.20$, $\rho = 2500\ \text{kg/m}^3$, $\sigma_y = 20\ \text{N/mm}^2$

Task 1

a) The concrete slab should be modeled using 4-node shell elements (S4 in Abaqus) and 800 mm characteristic size. Report your model in Abaqus by generating a figure of the model.

b) Run a simulation in Abaqus using the file established in a). View the analysis results in the visualization module. From the simulation, take out and report the following information:

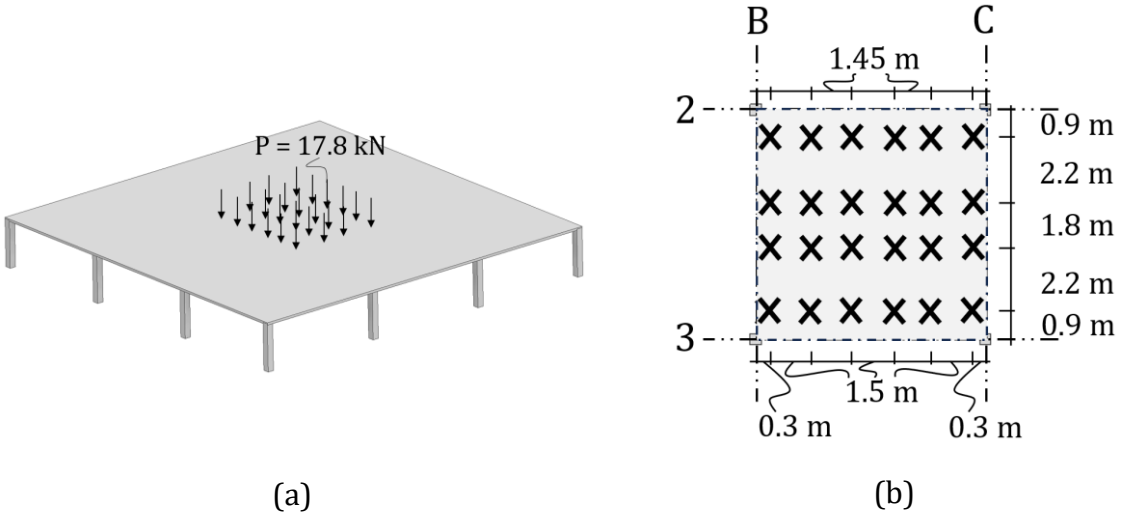
1) The deformed shape of the rooftop on top of the undeformed shape.
2) Contour plot of the vertical displacement on the deformed shape.
3) Contour plot of the von Mises stress on the deformed shape.
4) Contour plot of the maximum and minimum principal stresses on the deformed shape.
5) What is the critical element(s) of the structure? How do the stresses compare to the elastic limit of the material ($\sigma_y = 20\ \text{N/mm}^2$)?
6) Show the stress distribution over the cross section of the critical element(s).

c) Perform a convergence study and evaluate the maximum bending stress and the maximum displacement of the rooftop based on finite element analysis (FEA) of both linear and quadratic, triangular and quadrilateral shell elements. Explain how the convergence study has been conducted.

d) Assume now that the concrete material will experience cracks during the deformation. How does this change your modelling strategy for simulation of the displacements?

Task 2

We will now replace the uniform load by points loads P = 17.8 kN representing the forces imposed on the rooftop by the car tires (see Figure 2). However, the structural characteristics and material properties remain unchanged.



(a) (b)

Figure 2 – A rooftop supported by 16 columns and exposed to 24 points loads P = 17.8 kN representing the forces imposed on the rooftop by the car tires.

a) The concrete slab should be modeled using 4-node shell elements (S4 in Abaqus) and 800 mm characteristic size. Report your model in Abaqus by generating a figure of the model.

b) Run a simulation in Abaqus using the file established in a). View the analysis results in the visualization module. From the simulation, take out and report the following information:

1) The deformed shape of the rooftop on top of the undeformed shape.
2) Contour plot of the vertical displacement on the deformed shape.
3) Contour plot of the von Mises stress on the deformed shape.
4) Contour plot of the maximum and minimum principal stresses on the deformed shape.
5) What are the critical elements of the structure? Do the results change from those in Task 1b? How do the stresses compare to the elastic limit of the material ($\sigma_y = 20\ \mathrm{N/mm^2}$)?
6) Show the stress distribution over the cross-section of the critical element(s).

c) Perform a convergence study and evaluate the maximum bending stress and the maximum displacement of the rooftop based on finite element analysis (FEA) of both linear and quadratic, triangular and quadrilateral shell elements. Explain how the convergence study has been conducted.

d) Which loading case (uniform loading vs point loads) is most critical for the rooftop?