BEARING CAPACITY OF CIRCULAR FOOTING

This document describes an example that has been used to verify the ultimate limit state capabilities of PLAXIS. The problem involves the bearing capacity of a rigid circular footing on frictional soil.

> **Hint:** This validation needs considerable amount of disk space. Make sure you have at least 1.5 gigabytes of free space.

Used version:

- PLAXIS 2D - Version 2018.0
- PLAXIS 3D - Version 2018.0

Geometry: Figure 1 shows the geometry and material data for a smooth rigid circular footing with radius R = 1 m on a frictional soil.

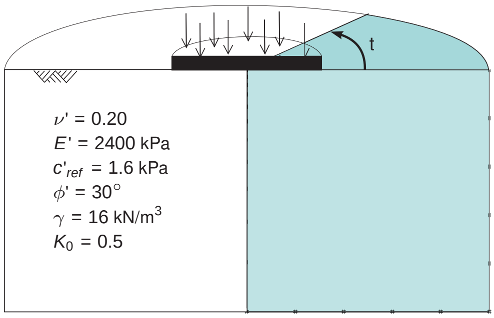

Figure 1 Problem geometry

In PLAXIS 2D the analysis is carried out using an axisymmetric model. The thickness of the soil layer equals 4 m. A prescribed displacement with negative y-direction equal to 0.5 m and horizontal direction free is applied at the top to simulate the penetration of the footing. Note that for an axisymmetric PLAXIS calculation, the mesh represents a wedge of an included angle θ of one radian; the calculated reaction force must therefore be multiplied by 2π to obtain the load corresponding to a full circular footing. This is a typical situation where the 15-noded elements are preferable, since lower order elements will over-predict the failure load. In order to locally refine the generated mesh, a vertical geometry line with length equal to 0.25 m is used at the right corner of the footing (Figure 2).

The geometry of the PLAXIS 3D model is presented in Figure 3. Due to symmetry, only a quarter of the problem geometry is modelled. The circular footing is defined as a surface prescribed displacement with negative z-direction equal to 0.5 m and horiontal directions (x,y) free. The calculated reaction force must be multiplied by 4 to obtain the load which corresponds to a full circular footing.

Materials: The material behaviour is represented by the Mohr-Coulomb model. Note that an associated plastic analysis is performed (ϕ = ψ = 30°) to match the theoretical

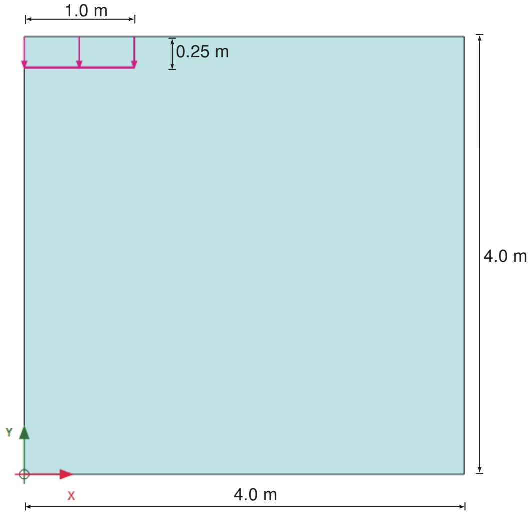

Figure 2 Model geometry (PLAXIS 2D)

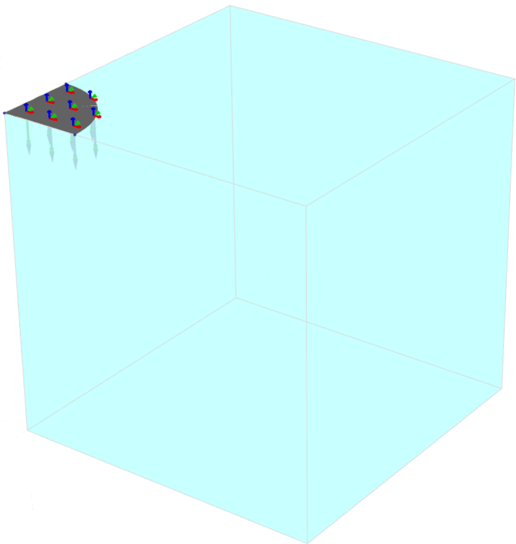

Figure 3 Model geometry (PLAXIS 3D)

solution. Tension cut-off is not used. The adopted material properties are presented in Figure 1.

Meshing: In the PLAXIS 2D model the *Medium* option is selected for the *Global coarseness*. The vertical geometry line at the corner of the footing is refined with a *Coarseness factor* of 0.2.

In the PLAXIS 3D model the *Medium* option is selected for the *Global coarseness*. The surface representing the footing is refined with a *Coarseness factor* of 0.1. In order to locally refine the generated mesh, *Coarseness factor* of 0.03125 is used at the perimeter of the circular footing.

Calculations: The initial stress distribution is generated in the *Initial phase* by using the *K0 procedure*. The prescribed displacement is activated in a separate phase (Phase 1). The calculation type is *Plastic analysis*. In PLAXIS 2D, a *Tolerated error* of 0.001 is selected and the *Max steps* parameter is set equal to 10000. For advanced calculation settings in PLAXIS 3D, the *Max steps* is set to 10000, the *Max unloading steps* is set to 10, the *Max load fraction per step* is set to 0.001, the *Max number of iterations* is set to 100, the *Desired min number of iterations* is set to 10, the *Desired max number of iterations* is set to 25 and the *Use line search* is set to true.

Output: The vertical load-displacement curve obtained from PLAXIS 2D and PLAXIS 3D is transformed to an average vertical stress-displacement curve by using Eqs. (1) and (2) respectively. In both cases, F_{vert} is the vertical load obtained from PLAXIS. Figure 4 presents the results. The collapse average vertical stress $p_{vert,max}$ is 227.64 kPa in PLAXIS 2D and 231.47 kPa in PLAXIS 3D.

Figures 5 and 6 illustrate the vertical displacement contours at failure obtained in PLAXIS 2D and PLAXIS 3D respectively.

$$p_{vert,2D} = \frac{F_{vert,2D} \times 2\pi}{\pi R^2} \tag{1}$$

$$p_{vert,3D} = \frac{F_{vert,3D} \times 4}{\pi R^2} \tag{2}$$

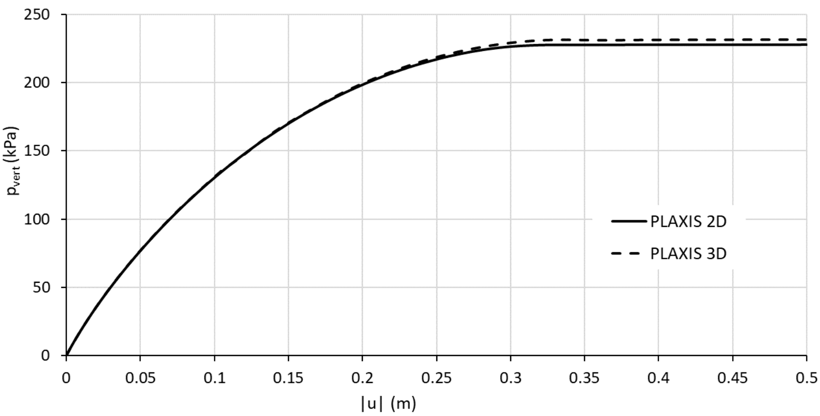

Figure 4 Average vertical stress-displacement curves for PLAXIS 2D and PLAXIS 3D

Verification: The exact solution for the collapse load problem is derived by Cox (1962) for $\gamma R/c$ = 10 and ϕ =30°. The solution reads:

$$p_{vert,max} = 141 \times c = 141 \times 1.6 = 225.6 \text{ kPa}$$

The relative error of the result calculated in PLAXIS 2D remains within 0.9% and in PLAXIS 3D within 1.7%.

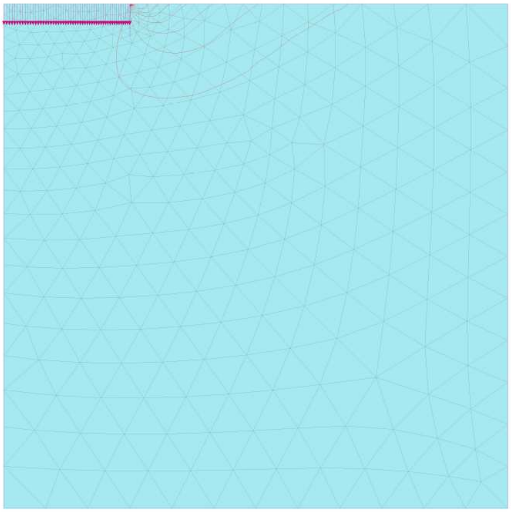

Figure 5 Vertical displacement contours at failure (PLAXIS 2D)

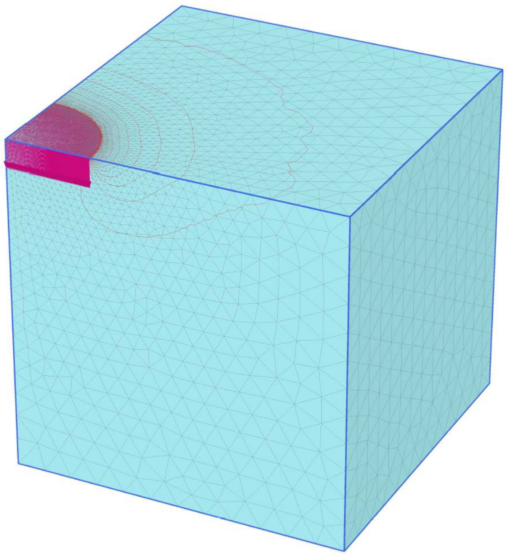

Figure 6 Vertical displacement contours at failure (PLAXIS 3D)

REFERENCES

[1] Cox, A.D. (1962). Axially-symmetric plastic deformations - indentation of ponderable soils. Int. Journal Mech. Science, 4, 341–380.