BEARING CAPACITY OF GROUND ANCHORS

This document describes an example that has been used to verify the bearing capacity of ground anchors in PLAXIS 3D. The test is performed with a ground anchor in loose and dense sand. The skin friction along the grout body is considered to be either constant or linear, in both dense and loose sand.

Used version:

- PLAXIS 3D - Version 2018.0

Geometry: The anchor's free length is simulated by using the *Node-to-node anchor* option. The grout body has a length of 4 m. It is simulated by using the *Embedded beam* option. The connection point between the embedded beam and the node-to-node anchor should be free to move and not fixed to the adjacent soil. This is adjusted by selecting the embedded beam and setting the option for the *Connection* type to *Free* via the *Selection explorer* window. The ground anchor is attached to a concrete block with dimensions $2 \times 2 \times 1$ m^3. The model layout is shown in Figure 1.

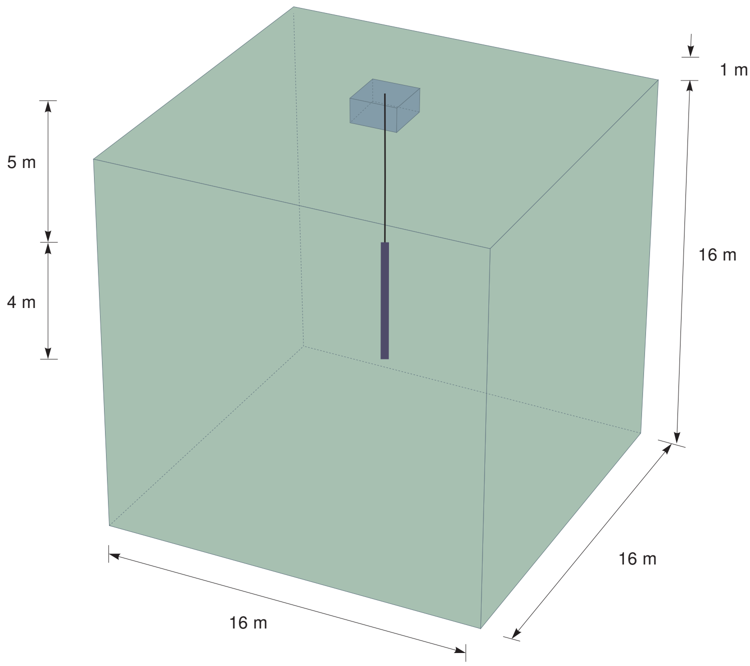

Figure 1 Problem geometry

Materials: The anchor is elastic with stiffness E'A = 4.095×10^5 kN. The skin friction properties of the ground anchor are defined as:

Loose sand:

Constant skin friction (CS): $T_{skin,start,max}$ = 50 kN/m $T_{skin,end,max}$ = 50 kN/m

Linear skin friction (LS): $T_{skin,start,max}$ = 0 kN/m $T_{skin,end,max}$ = 100 kN/m

Dense sand:

Constant skin friction (CS): $T_{skin,start,max}$ = 188 kN/m $T_{skin,end,max}$ = 188 kN/m

Linear skin friction (LS): $T_{skin,start,max}$ = 0 kN/m $T_{skin,end,max}$ = 376 kN/m

The remaining properties of the grout body are:

$$E = 2 \times 10^7 \text{ kN/m}^2, \text{ Diameter} = 0.125 \text{ m}$$

The concrete block is modelled as a non-porous linear elastic material:

$$\gamma = 25 \text{ kN/m}^3, \ E = 2.80 \times 10^7 \text{ kN/m}^2, \ \nu = 0.15$$

The loose sand as well as the dense sand are modelled by the Mohr-Coulomb model. The properties of the loose sand are:

$$\gamma_{unsat} = 16 \text{ kN/m}^3, \ \gamma_{sat} = 18 \text{ kN/m}^3, \ E' = 4.5 \times 10^4 \text{ kN/m}^2, \ \nu' = 0.3$$
$$c' = 0.1 \text{ kN/m}^2, \quad \varphi' = 28 \text{ deg}, \quad \psi = 0 \text{ deg}$$

The properties of the dense sand are:

$$\gamma_{unsat} = 17 \text{ kN/m}^3, \ \gamma_{sat} = 20 \text{ kN/m}^3, \ E' = 10.5 \times 10^4 \text{ kN/m}^2, \ \nu' = 0.3$$
$$c' = 0.1 \text{ kN/m}^2, \quad \varphi' = 35 \text{ deg}, \quad \psi = 5 \text{ deg}$$

Meshing: The *Medium* option is selected for the *Element distribution*. A *Coarseness factor* equal to 1.0 is assigned to entire model, apart from the *Embedded beam* and the *Node-to-node anchor*, for which a *Coarseness factor* of 0.5 is used. The resulting generated mesh is depicted in Figure 2. The node located at the top (8.0, 8.0, -4.0) and the bottom (8.0, 8.0, -8.0) of the ground anchor is selected to present the results. Attention should be payed in order to select the nodes of the *Embedded beam* and not any adjacent soil node.

Calculations: The bearing capacity of the ground anchor is tested in 4 different phases, considering constant and linear skin friction, in both loose and dense sand. A prestress force of 1000 kN is applied via the *Node-to-node anchor*. In the *Numerical control parameters* menu, the *Tolerated error* is set to 0.001 and the *Max load fraction per step* is set to 0.1, for all considered calculation phases.

Output: In Figure 3 the axial force at the top of the anchor N_{top} is plot against displacements $|u|$, while Figure 4 illustrates the axial force at the bottom of the anchor N_{bottom} over displacements $|u|$. The free top of the anchor moves promptly as the axial load is applied. The bottom anchor point does not have the same behaviour due to the axial skin resistance of the anchor. This is more apparent in case of dense sand conditions, for which a higher value of skin resistance is assigned to the anchor.

In loose sand, the maximum axial force in the anchor is 200.20 for both, a constant skin

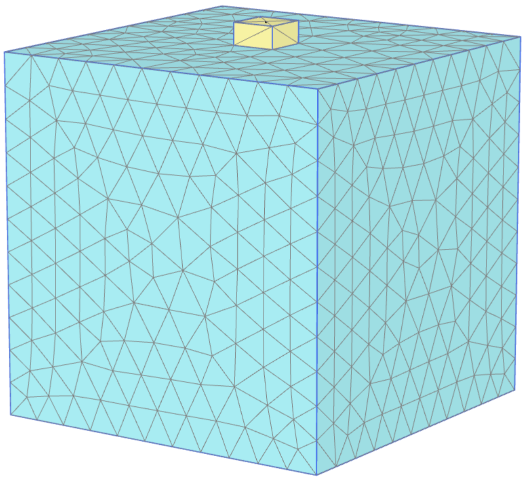

Figure 2 The resulting mesh

friction distribution (CS) and a linear skin friction distribution (LS). This is consistent for the top and the bottom of the anchor. In dense sand, the maximum axial force in the anchor is 752.75 and 752.77 kN for a constant skin friction distribution (CS) and a linear skin friction distribution (LS) respectively. This is consistent for the top and the bottom of the anchor as well.

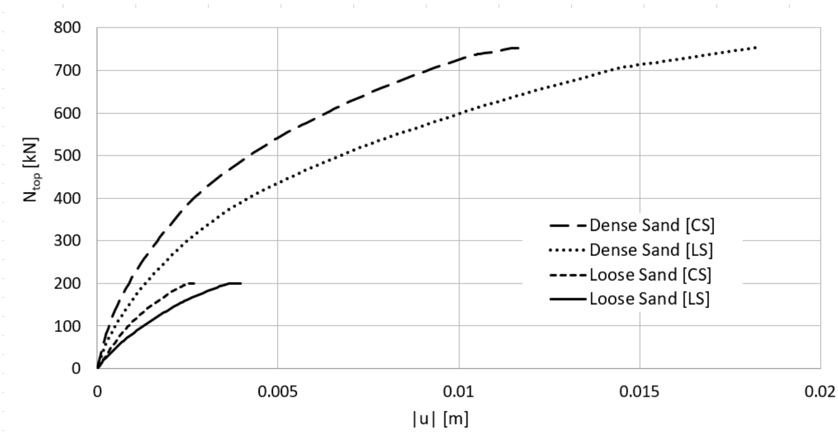

Figure 3 Axial force at the top of the anchor against displacements

Verification: The theoretical solution for the total bearing capacity is presented below (Ostermayer & Barley, 2003).

Loose sand:

$$F_{max} = 4\text{m} \times 50\text{kN/m} = 200\text{kN}$$

Dense sand:

$$F_{max} = 4\text{m} \times 188\text{kN/m} = 752\text{kN}$$

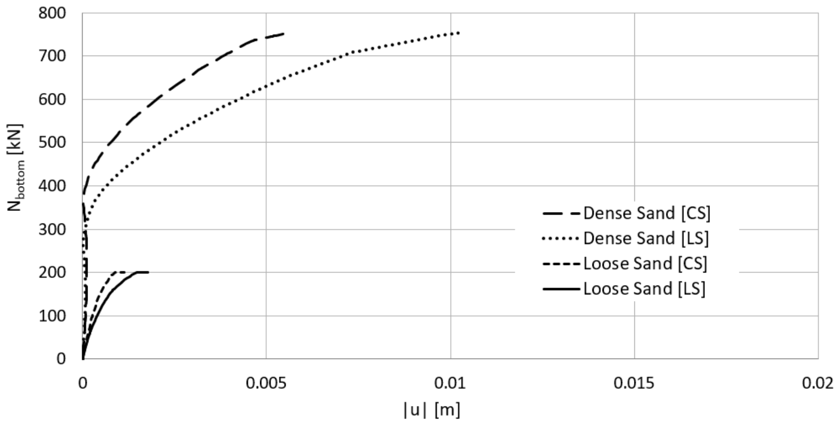

Figure 4 Axial force at the bottom of the anchor against displacements

The results indicate an error less than 0.2% for both loose and dense sand. In both soil materials, the ground anchor shows a softer behavior in case of a linear skin friction distribution (LS). This is caused by early slip at the bottom of the grout body, when the prestress is still rather low, resulting in larger displacements. In case of a constant skin friction distribution (CS), the whole grout body remains elastic. Smaller displacements occur until a higher value of the prestress force is reached.

REFERENCES

[1] Ostermayer, H., Barley, T. (2003). Ground anchors. Geotechnical Engineering Handbook, 2, 169–219.