UNCONFINED FLOW THROUGH A SAND LAYER

This document verifies that groundwater flow principles are correctly implemented in PLAXIS. Unconfined flow through a sand layer is studied and the resulting phreatic surface and total discharge are verified.

Used version:

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

Geometry: The model geometry in PLAXIS 2D is presented in Figure 1. The height of the sand layer equals 3.0 m, while its length equals 10.0 m. The bottom of the layer is set to be *Closed* (impervious), represented by a black thick line in Figure 1. The groundwater head is prescribed at 2.0 m on the left boundary and at 1.0 m on the right boundary.

In PLAXIS 3D, the model is extended by 1 m in the y-direction. Additionally, both groundwater flow boundaries in y-direction are set to be *Closed*.

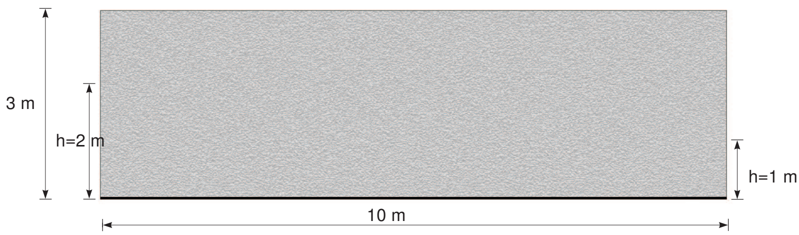

Figure 1 Problem geometry and groundwater flow boundary conditions

Materials: The *Standard* hydraulic model (*Coarse* material) is used to model the unsaturated flow. The adopted material parameters are:

Soil: Linear elastic Drained E'=1 kN/m^2 k=1 m/day

Meshing: In PLAXIS 2D, the *Very fine* option is selected for the *Element distribution*, while in PLAXIS 3D the *Medium* option is used. The right model boundary is refined with a *Coarseness factor* of 0.05. Figures 2 and 3 illustrate the generated finite element mesh in PLAXIS 2D and PLAXIS 3D correspondingly.

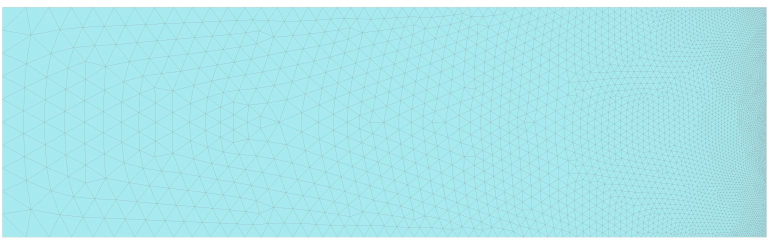

Figure 2 Finite element mesh in PLAXIS 2D

Calculations: The calculations are performed using the *Flow only* mode with *Steady state groundwater flow* as the *Pore pressure calculation type*.

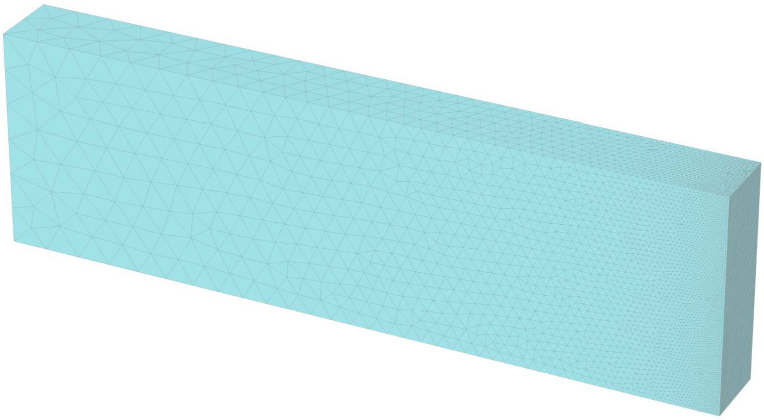

Figure 3 Finite element mesh in PLAXIS 3D

Output: Figures 4 and 5 present the flow field for PLAXIS 2D and PLAXIS 3D respectively (vectors are scaled up 0.5 times). In PLAXIS 3D a vertical cross-section at the middle of the model (*y*=0.5 m) is used.

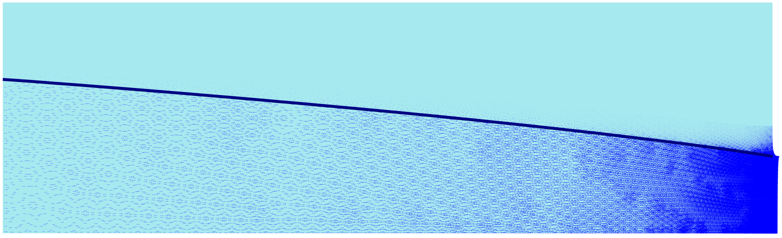

Figure 4 Flow field in PLAXIS 2D

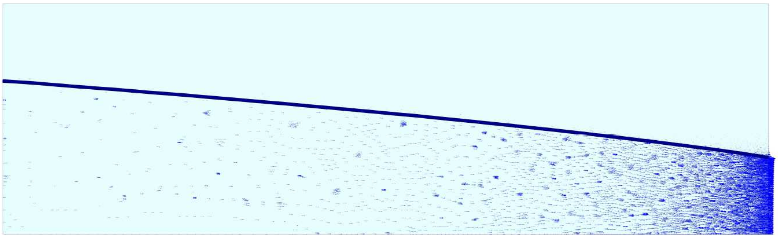

Figure 5 Flow field in PLAXIS 3D (vertical cross-section at *y*=0.5 m)

Figures 6 and 7 depict the distribution of the groundwater head, varying from 2.0 m at the left model boundary to 1.0 m at the right model boundary, in PLAXIS 2D and PLAXIS 3D respectively. As discussed above, in PLAXIS 3D a vertical cross-section at the middle of the model (y=0.5 m) is considered. It can be seen that the contour lines are nearly vertical, which means that the pore pressure distribution in each vertical cross section is nearly hydrostatic.

If the change of the groundwater head would occur along a smaller length, then the pore pressure distribution would not be hydrostatic, particularly next to the right model boundary.

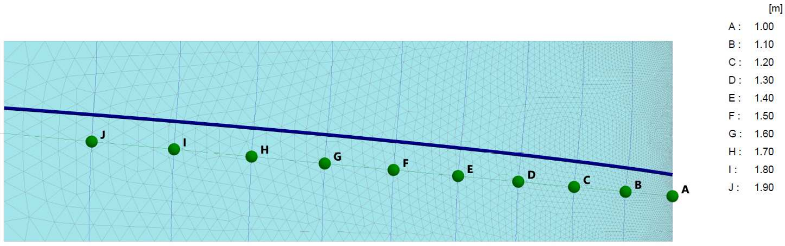

Figure 6 Contour lines of groundwater head in PLAXIS 2D

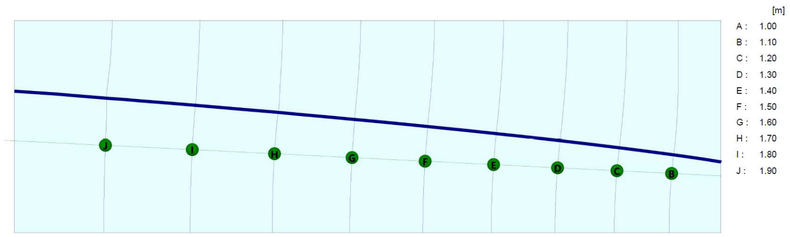

Figure 7 Contour lines of groundwater head in PLAXIS 3D (vertical cross-section at y=0.5 m)

Verification: Under the assumption of a hydrostatic pore pressure distribution for each vertical cross section, the total discharge through the layer Q can be approximated with Dupuit's formula for unconfined flow (Dupuit, 1863):

$$Q = k\frac{\phi_1^2 - \phi_2^2}{2L} \tag{1}$$

where k is the permeability, L is the length of the layer and ϕ_1, ϕ_2 represent the groundwater head at the left and right model boundaries respectively.

In PLAXIS, the total discharge is derived by taking a cross-section close to the right model boundary. Comparison of the results obtained from PLAXIS and the analytical solution is presented in Table 1.

Table 1 Comparison between total discharge obtained from PLAXIS and Dupuit's formula

Total discharge (m^3/day/m)			Error (%)	
Dupuit	PLAXIS 2D	PLAXIS 3D	PLAXIS 2D	PLAXIS 3D
0.150	0.154	0.154	2.7	2.7

It is concluded that the results obtained from the analytical formulation and PLAXIS are in good agreement. The difference between the numerical and the analytical solution is mainly due to the unsaturated flow that occurs above the phreatic level, which is taken into consideration in the numerical model. It should be noted that use of different hydraulic models influences the error as well.

REFERENCES

[1] Dupuit, J. (1863). Études théoriques et pratiques sur le mouvement des eaux dans les canaux découverts et a travers les terrains perméables avec des considérations relatives au régime des grandes eaux, au débouché a leur donner et a la marche des alluvions dans les rivieres a fond mobile. Dunod, Paris.