DRAIN

This document verifies that groundwater flow principles are correctly implemented in PLAXIS. A soil column with a drain inside is simulated. The total amount of water leaving through the drain is calculated in PLAXIS and the numerical results are compared to the closed form solution proposed by Dupuit (1863).

Used version:

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

Geometry: The model geometry in PLAXIS 2D is presented in Figure 1. A plane-strain model with 15-noded elements is used. The phreatic level is initially set at 18 m to generate a groundwater head of 18 m at the left and right model boundaries. A vertical drain is placed at the midline of the soil cluster (x = 25 m). The groundwater head in the drain *h* is set equal to 10 m. All groundwater flow boundaries except for the bottom boundary are set to *Seepage* (open). The bottom model boundary is set to *Closed* (impervious).

In PLAXIS 3D, the same model as described above is used, extended by 1 m in y-direction. A *Surface drain* is used, placed vertically at the middle of the model (x = 25 m) and extended by 1 m in y direction. Both groundwater flow boundaries in y-direction are set to be *Closed*. Figure 2 illustrates the model geometry in PLAXIS 3D.

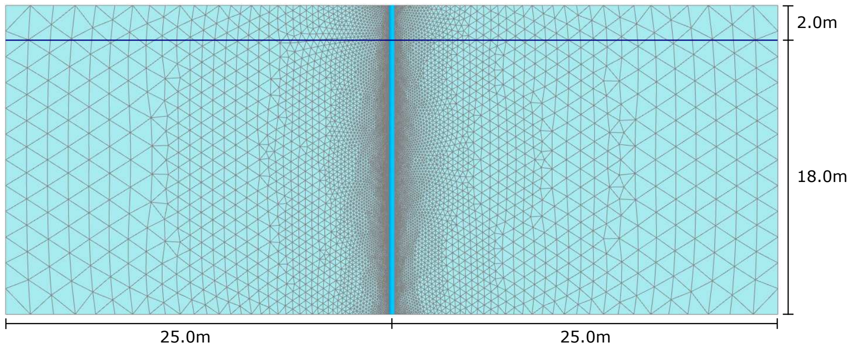

Figure 1 Problem geometry and generated mesh (PLAXIS 2D)

Materials: The soil is modeled as *Drained*, *Linear elastic*. The *Standard* hydraulic model (*Van Genuchten*) for *Coarse* material is used to model the unsaturated flow conditions above the phreatic level. Permeability *k* equals 1 m/day in every direction. 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*. The geometry line which represents the drain is refined with a *Coarseness factor* of 0.03125. In PLAXIS 3D, the *Medium* option is selected for the *Element distribution* and the geometry surface which represents the drain is refined with a *Coarseness factor* of 0.1. The generated mesh is illustrated in Figures 1 and 2 for PLAXIS 2D and PLAXIS 3D respectively.

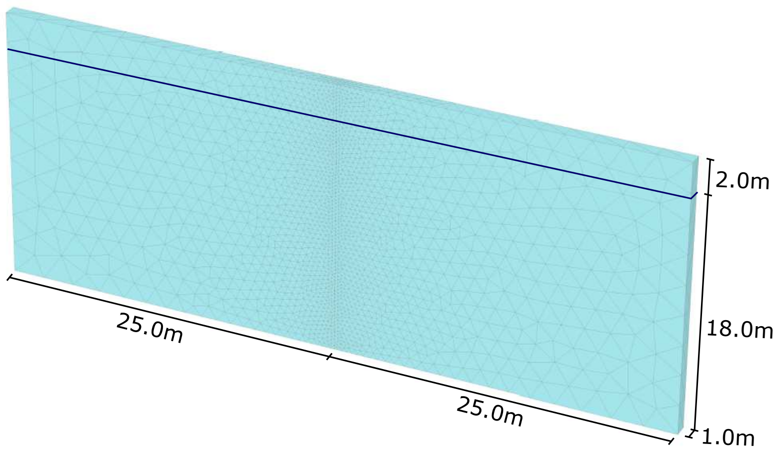

Figure 2 Problem geometry and generated mesh (PLAXIS 3D)

Calculations: The calculations are performed using the *Flow only* calculation type in the Initial phase. The drain is activated and the groundwater flow boundary conditions are adjusted as described above.

Output: The active pore pressures and the degree of saturation under steady-state conditions are presented in Figures 3 and 4 for PLAXIS 2D. Figures 5 and 6 illustrate the corresponding results for PLAXIS 3D, considering a vertical cross section at y = 0.5 m. In Figures 3 and 5, suction above the resulting phreatic level is indicated with positive values of the pore pressure.

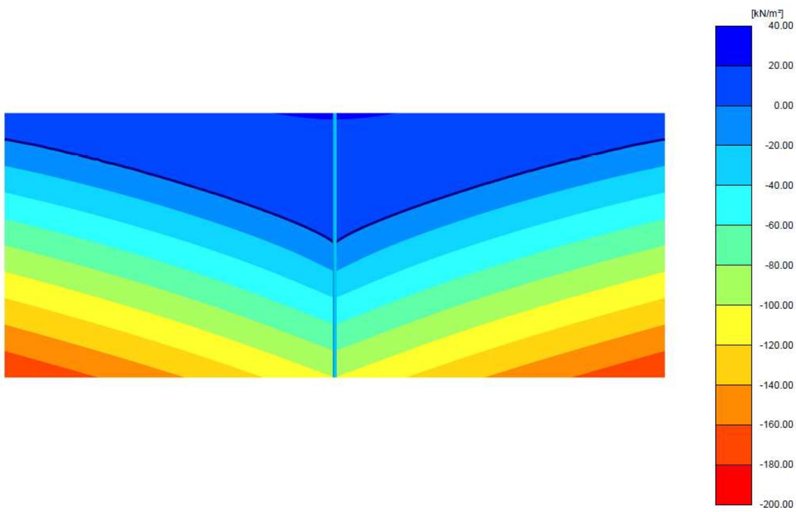

Figure 3 Active pore pressures obtained in PLAXIS 2D

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

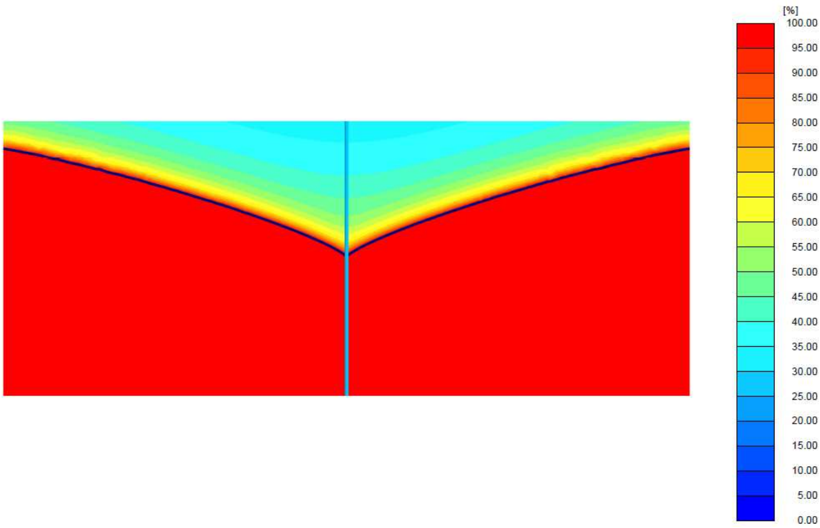

Figure 4 Degree of saturation obtained in PLAXIS 2D

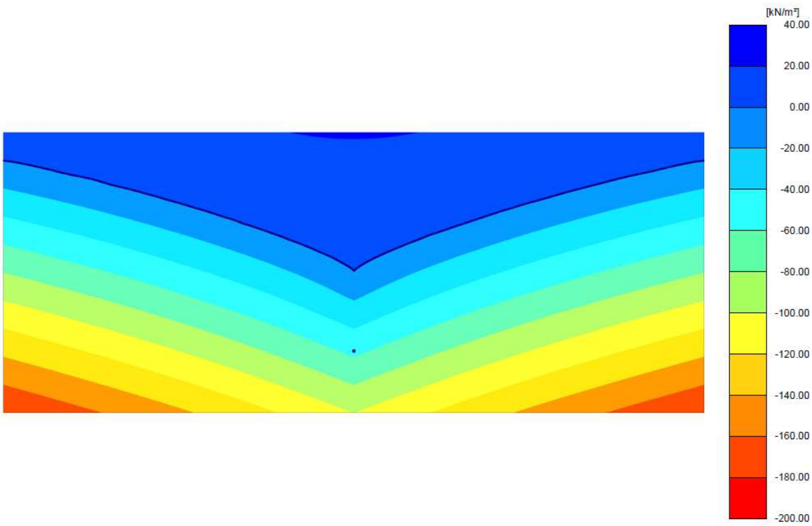

Figure 5 Active pore pressures obtained in PLAXIS 3D (y = 0.5 m)

for unconfined flow (Dupuit, 1863):

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

where k is the permeability and L is the horizontal distance between the left (or right) model boundary and the drain. ϕ_1 and ϕ_2 represent the groundwater head at the left (or right) model boundary and at the drain respectively.

In PLAXIS, the total discharge through the dam is derived by taking a vertical cross-section close to the drain, e.g. at x = 24.0 m. Figures 7 and 8 present the corresponding results for PLAXIS 2D and PLAXIS 3D respectively. Comparison of the

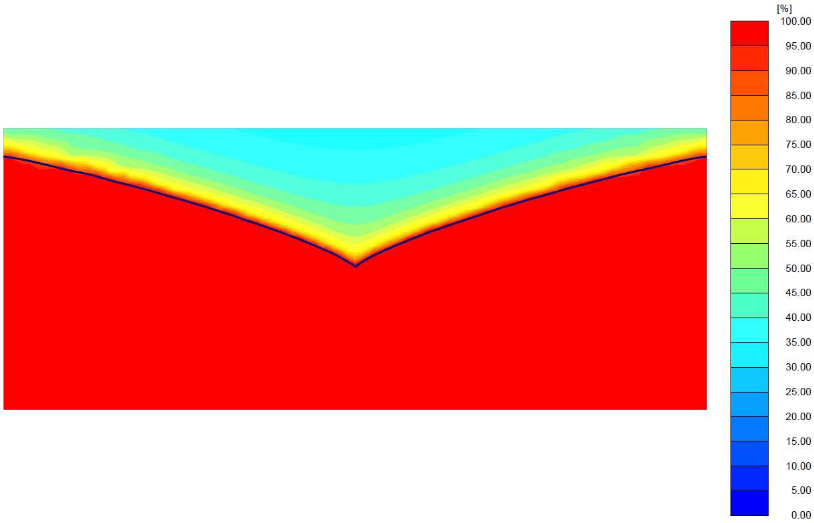

Figure 6 Degree of saturation obtained in PLAXIS 3D (y = 0.5 m)

results obtained from PLAXIS and the analytical solution is presented in Table 1.

It is concluded that the results obtained from the closed form solution 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.

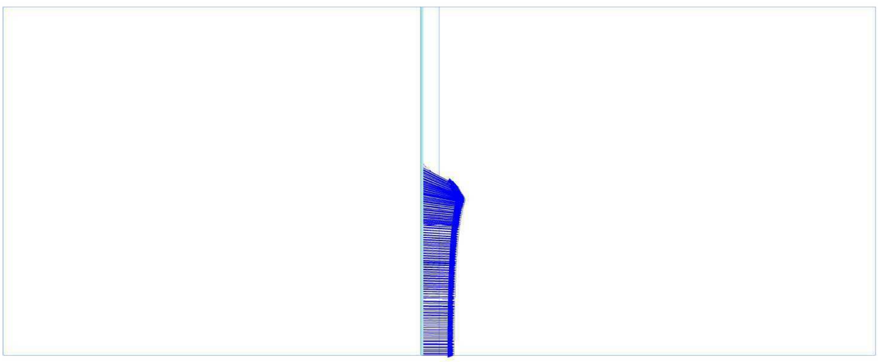

Figure 7 Total discharge obtained in PLAXIS 2D (x = 24.0 m)

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
4.480	4.489	4.483	0.2%	0.06%

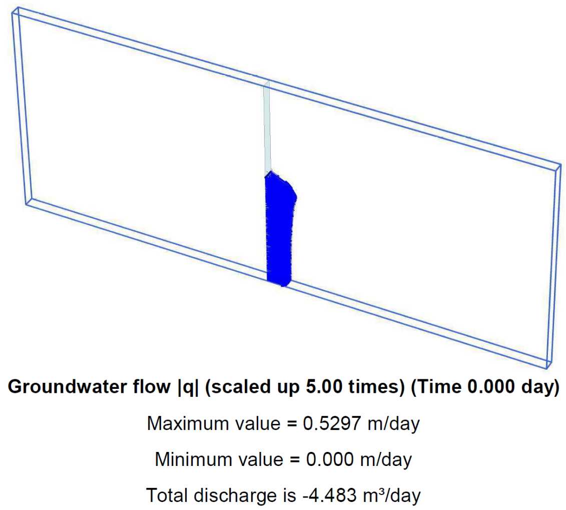

Figure 8 Total discharge obtained in PLAXIS 3D (x = 24.0 m)

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.