Muskat Problem

Keywords

2D/3D continuum elements, Two-phase, phreatic surface, seepage boundary conditions, partially saturated.

Problem Description

The Muskat problem considers the unconfined flow of water through a homogeneous dam. The problem was solved by Kang-Kun and Leap [1] who presented a graphic solution for different dam dimensions and water levels as shown in figure 1. The model geometry takes the base length ***L*** as 1m and the water depth on the upstream side ***h*** of 2m. The water depth on the downstream side h_o is 0.4m. Reading from the graph ***s/h***=0.42, so the length of the seepage surface ***s*** is 0.84m and the phreatic surface intersects the dam downstream edge at a height of 1.24m.

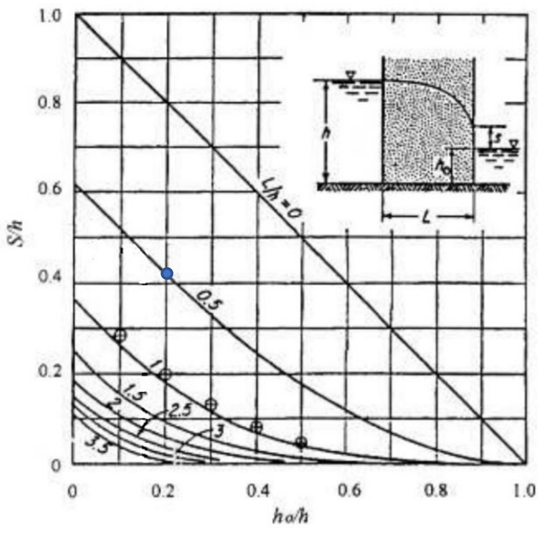

Figure 1. Graphic solution to Muskat problem

Discretisation

The problem is meshed with quadrilateral plane strain elements (QPN8P) with quadratic interpolation in 2D and hexahedral elements (HX20P) in 3D. The bottom of the dam is fully restrained. Two phreatic surfaces are defined, one for the upstream side and second for the downstream. Seepage boundary conditions are applied to the downstream side of the dam above the free water surface.

Figure 2 shows the problem geometry, mesh and boundary conditions.

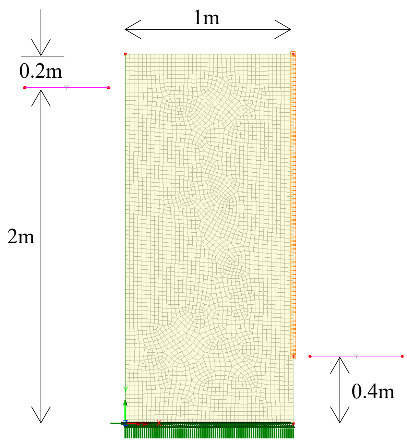

Figure 2. 2D Problem geometry and mesh

Material Properties

The wall and water flow properties are listed in table 1.

Table 1: Material properties

Saturated Mass density	Young's modulus, E	Poisson's ratio, ν	Porosity	Hydraulic conductivity, k	Partially saturated - constant water content	
					Residual saturation	Full saturation
2.4 t/m^3	100E6 kPa	0.2	0.2	1.0E-10 m/s	0.0	1.0

Loading Conditions

Gravity loading is applied.

Modelling Hints

This problem is slower to converge than normal, so the number of permissible iterations is increased to 30. On the downstream side the seepage boundary conditions start from the phreatic surface upwards. The seepage boundary should not be overlapped with the phreatic surface to avoid conflicting pressure definitions.

Comparison

Height at which phreatic surface crosses downstream edge

Kang-Kun and Leap	2D mesh	3D mesh
1.24m	1.26m	1.26m

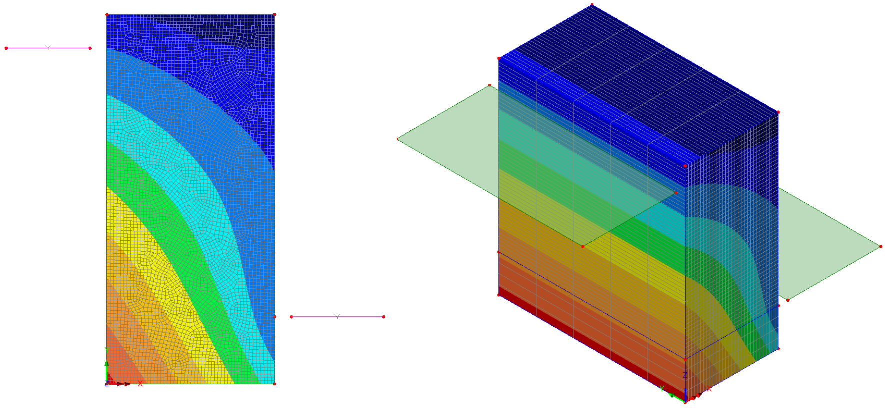

Figure 3. Pressure contour plots for 2D and 3D solutions

References

[1] Kang-Kun L., Leap I.D., Simulation of a free surface face using boundary-fitted coordinate system method, Journal of hydrology, 297-309, 1997.

Input Data

Muskat_2D.lvb

Muskat_3D.lvb