Drainage of an excavation

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1 Introduction

This benchmark represents a scenario in which drainage of a shallow excavation is addressed. From Bernoulli's equation, the total energy of water at a given point equals the sum of potential energy, pressure work, and kinetic energy.

$$E = mgz + uV + \frac{mv_\mathrm{w}^2}{2} \tag{1}$$

where $[E] = \mathrm{kN\,m}$ is energy per unit mass in flow, $[m] = \mathrm{kg}$ is mass, $[g] = \mathrm{m\,s^{-2}}$ is the gravitational acceleration, $[z] = \mathrm{m}$ is the elevation of the point above a reference plane, $[u] = \mathrm{kN\,m^{-2}}$ is the water pressure, $[V] = \mathrm{m^3}$ is volume, and $[v_\mathrm{w}] = \mathrm{m\,s^{-1}}$ is the water velocity. By dividing the energy by volume, one may obtain the equation in the following form:

$$\frac{E}{V} = z\gamma_\mathrm{w} + u + \frac{\gamma_\mathrm{w}}{2g}v_\mathrm{w}^2 \tag{2}$$

where $[\gamma_\mathrm{w}] = \mathrm{kN\,m^{-3}}$ is specific weight of water. Since the flow velocity of the groundwater is usually quite low, the kinetic energy can usually be neglected. Rearranging the above equation, the hydraulic head in m is given as

$$h = z + \frac{u}{\gamma_\mathrm{w}} \tag{3}$$

2 Model setup

The numerical model is motivated by the example described by Katzenbach, 2013. The two-dimensional representation of the excavation has 65 m length, and 60 m and 30 m height in the West and East, respectively. The bottom and lateral sides of the domain are set to no-flow. Likewise, the retaining wall is taken as impermeable. The geometry and boundary conditions are shown in Fig. 1

The head-based calculations are done with the steady-state diffusion process in OGS, while the pressure-based calculations use the liquid flow process.

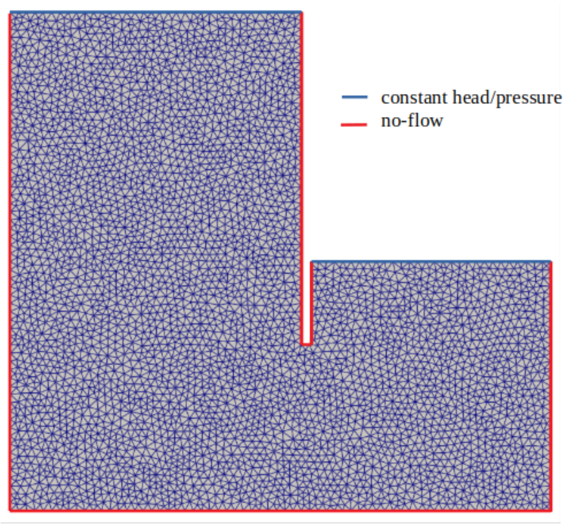


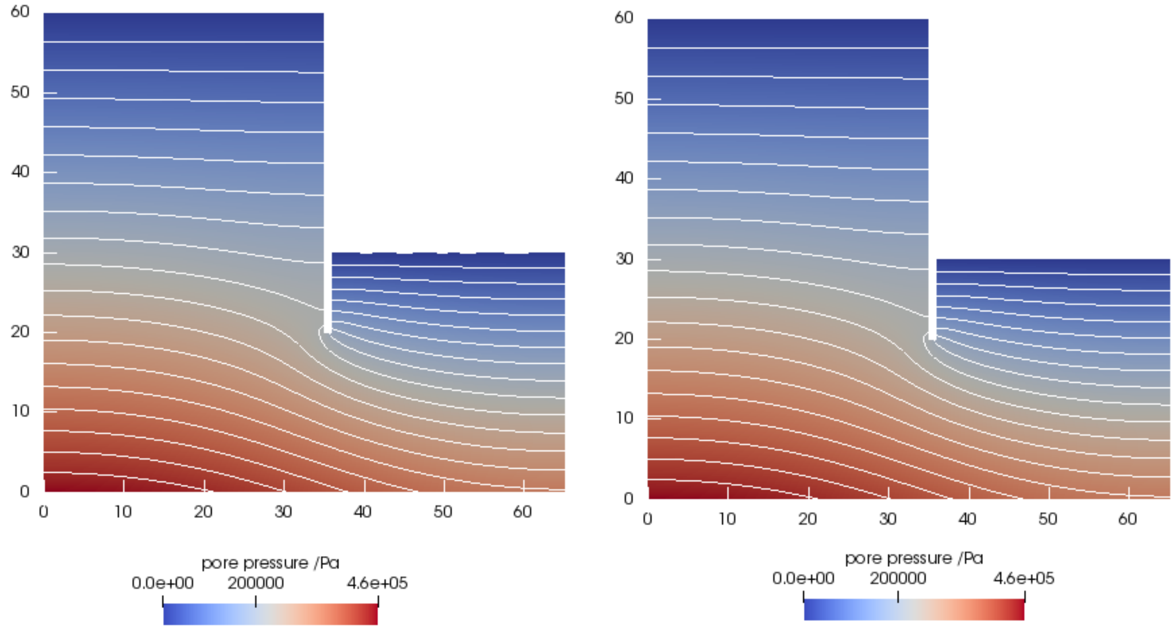
Figure 1: Model geometry, mesh and boundary conditions used for the numerical simulation.

2.1 Head-based

In this scenario, the top boundaries are defined as fixed-head boundary conditions.

2.2 Pressure-based

This scenario assumes a constant pressure at the top boundaries.



(a) head-based (b) pressure-based

Figure 2: Pore pressure distribution and isobars.

3 Input files

The input files for the OGS are listed below. One may change initial and boundary conditions, and geometry and mesh files.

3.1 Head-based

The project file is *drainage_excavation.prj*. The input mesh file is *drainage_excavation.vtu* and the geometry file used to describe the boundary conditions is *drainage_excavation_geo.gml*.

3.2 Pressure-based

The project file is *drainage_LiquidFlow.prj*. The input mesh file is *drainage_LiquidFlow.vtu* and the geometry file is *drainage_LiquidFlow_geo.gml*.

4 Results

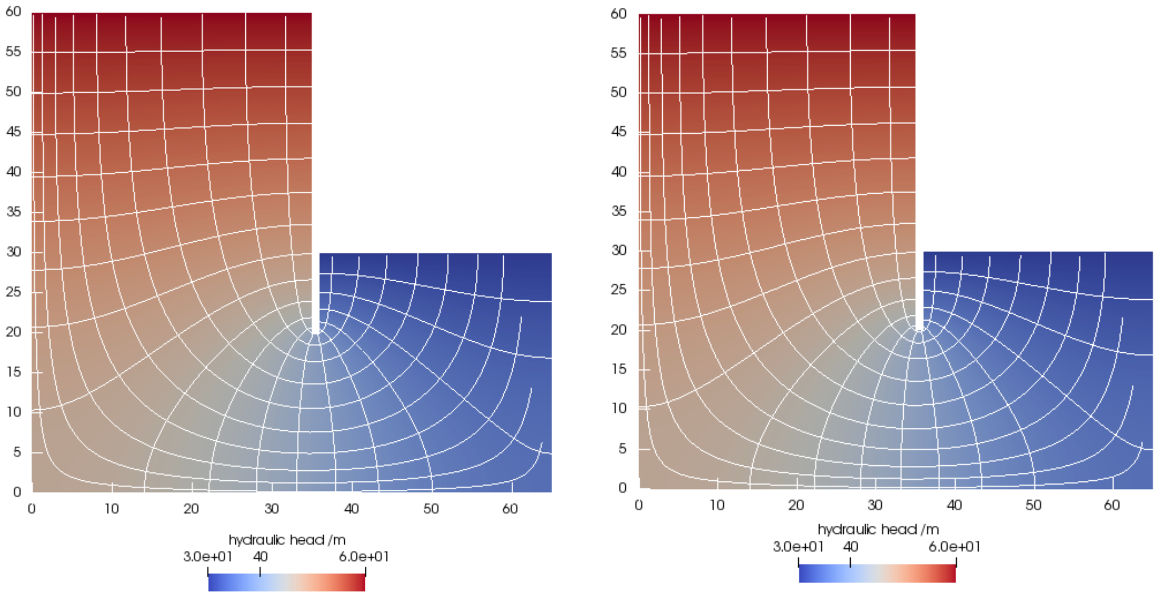
The results obtained from both process models are essentially the same meaning that both implementations can be employed consistently when parameterized equivalently.

The pore pressure distribution throughout the model domain are shown in Fig. 2 by pressure contours. The pressure increases due to the increase of the hydrostatic pressure and is altered from the hydrostatic state due to flow-induced pressure losses.

The resulting hydraulic head, hydraulic head contours and flow streamlines are displayed in Fig. 3. The flow velocity varies along the streamlines, and streamlines get closer together where the flow velocity is higher. In these regions, the higher potential gradients are illustrated by closer hydraulic head lines.

The water nodal fluxes obtained from the liquid flow implementation are presented in Fig. 4. A positive value (in red) represents the water inflow to the excavation while a negative value (in blue) represents the outflow. Due to the steady state condition, the sum of total water inflow and outflow equals zero (cf. Fig. 4). The total discharge from the excavation is (assuming a permeability of $k = 10^{-12}\,\mathrm{m}^2$)

$$Q_{\text{outflow}} = 0.000\,11\,\mathrm{m}^3\,\mathrm{s}^{-1}\,\mathrm{m}^{-1} \tag{4}$$



(a) head-based

(b) pressure-based

Figure 3: Hydraulic head distribution, isohypses and streamlines.

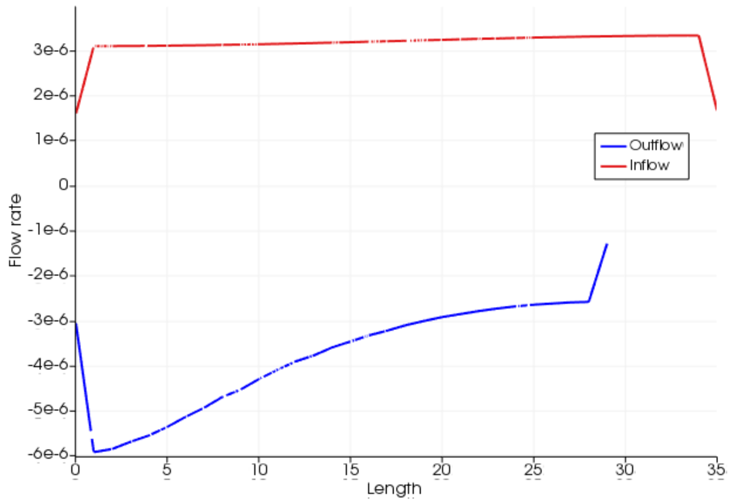


Figure 4: Nodal fluxes obtained from the liquid flow implementation in $\mathrm{m}^3\,\mathrm{s}^{-1}\,\mathrm{m}^{-1}$.

References

Katzenbach, Rolf (2013). “Grundwasserhydraulik”. In: *Geotechnical institute, TU Darmstadt*, pp. 1–39.