Seepage Face
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Appendix A Additional Information
1 Description

This tutorial presents a groundwater flow analysis. It describes the determination of a seepage face by means of a nonlinear steady state analysis. The model is a rectangular vertical cross-section of $1.62 \times 3.50$ m [Fig. 1]. At side BC there is a potential height of 3.22 m and at side AD a potential height of 0.84 m. It is expected that a seepage point will occur somewhere at side AD. The material has a saturated hydraulic conductivity of $1e^{-6}$ m/s. A theoretical solution for this problem has been given by Muskat (1937)\footnote{Muskat, \textit{The Flow of Homogeneous Fluids Trough Porous Media}, 1937}: a seepage point at 2.06 m above point A.

Figure 1: Geometry and characteristics of the model
2 Finite Element Model

We start a new project for a groundwater flow analysis with generalized plane strain. The model size is set to 100 m. The units used are presented in Figure 4. We set the direction of gravity to $Y$. 

Main menu ➔ File ➔ New [Fig. 2]
Geometry browser ➔ Reference system ➔ Units [Fig. 3]
Property Panel [Fig. 4]
Geometry browser ➔ Reference system ➔ Definitions [Fig. 5]
2.1 Geometry

The geometry of the model consists of a rectangular sheet with corner points A, B, C, D respectively. An additional point is added on the right side at the location of the fixed potential height. The \( X, Y, Z \) coordinates are: (0, 0, 0), (1.62, 0, 0), (1.62, 3.22, 0), (1.62, 3.5, 0), (0, 3.5, 0).
3 Properties

We define groundwater flow properties to the seepage face. Using the button, we can enter the tabular properties of the hydraulic conductivity.

**Main menu** → Geometry → Assign → Shape Properties [Fig. 8]
Shape Properties → Material → Add material [Fig. 9] → Edit material [Fig. 10]

![Figure 8: Property assignments seepage face](https://dianafea.com)
![Figure 9: Add new material](https://dianafea.com)
![Figure 10: Edit material](https://dianafea.com)
![Figure 11: Edit conductivity properties](https://dianafea.com)
Shape Properties ➔ Geometry ➔ Add new geometry [Fig. 12]

Figure 12: Edit geometry
3.1 Boundary Conditions

First we apply a constant pressure head of 3.22 m at the right-hand side of the model. However, we first need to fix the potential (in this case the head) of this edge.
Before we define the boundary conditions at the left-hand side, we define the connection since the boundary conditions on the left-hand side are dependent on these. It is also necessary to define the material and geometry properties for this connection.
Figure 20: Connection property assignments

Figure 21: Connection properties left-hand side
Now we can define an outside head pressure of 0.84 m at the left-hand side of the model. We make use of the earlier defined connection **Boundaries**.

**Main menu** ➔ **Geometry** ➔ **Assign** ➔ **Add ground water conditions** ![Fig. 22](https://dianafea.com)

![Figure 22: Attach boundary condition](https://dianafea.com)

![Figure 23: Connection properties left-hand side](https://dianafea.com)
3.2 Mesh

We create a mesh by using the seeding method element size with a desired element size of 0.14 m. After that we create the mesh.

[Fig. 24]

Figure 24: Mesh properties

[Fig. 25]

Figure 25: Finite element mesh
4 Linear Steady State Groundwater Flow

4.1 Commands

We first perform a preliminary linear steady state analysis to check the finite element model by plotting the resulting pressure height, fluxes and hydraulic head for the groundwater flow elements. In order to check these results we need to specify these variables as output for this analysis. For the FLUX TOTAL GLOBAL we specify the location in the integration points.
4.2 Results

We present the contour plot of the total head H and the vector plot for the groundwater flux FLXYZ in Figure 31 and Figure 33 respectively. In the view settings panel [Fig. 32] we specify some result settings for Figure 33. We hide the boundaries in the element sets in the mesh browser in order to have a clearer plot.
It is also instructive to show the phreatic line. We can do this by plotting the pressure head HP with one contour level. Again, we need to specify some result plot properties in the view settings panel [Fig. 35].

The phreatic line appears to be linear. This is due to the fact that a linear analysis is carried out. In reality this is a nonlinear problem, so we continue with a nonlinear steady state analysis.

Figure 34: Pressure head - linear analysis

Figure 35: View plot settings
5 Nonlinear Steady State Groundwater Flow

5.1 Commands

We copy Analysis1 creating Analysis 2. We add to this new analysis a nonlinear command [Fig. 37]. The output properties are copied from Analysis 1. We select Analysis2 and run this analysis.

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Analysis browser ➔ Analysis1 ➔ Duplicate analysis [Fig. 31]
Analysis browser ➔ Analysis2 ➔ Steady state ground water flow ➔ Execute groundwater flow analysis ➔ Edit properties [Fig. 36]
Main menu ➔ Analysis ➔ Run selected analysis

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Figure 36: Analysis browser
Figure 37: Nonlinear properties
5.2 Results

We present the contour plot of the pressure head [Fig. 38]. In the view settings panel we set the contour levels to equidistant levels and specify the number of contour levels to 25 [Fig. 39]. Also the vector plot of the groundwater flux is presented [Fig. 40].
Finally, we plot the phreatic line [Fig. 41] to get the seepage point. We do this in the same manner as done for the linear steady state groundwater flow analysis [Fig. 42]. With the [equation] we can measure the distance between point A and the seepage point (see Figure 1).
6 Verification

The theoretical solution given by Muskat (1937)[1] is a seepage point of 2.06 m above the bottom of the model. From the plot of the phreatic line we can determine that the phreatic line reaches the left side of the model (the seepage point) at 2.129 m above the bottom, which seems to be quite accurate. The theoretical solution assumes a perfect separation between saturated and unsaturated areas but in reality, and also in this DianaFE analysis, a partly saturated area will occur just above the phreatic line. Due to this partly saturated area the seepage point will be situated at a bit higher level.
Appendix A  Additional Information

Folder: Tutorials/SeepageFace

Number of elements $\approx 300$

Keywords:
- ANALYS: flow growa nonlin steady.
- CONSTR: head.
- ELEMEN: b2gw flow ground q4gw.
- LOAD: elemen head node.
- MATERI: hydcdn isotro permea.
- OPTION: direct.
- POST: binary ndiana.
- PRE: dianai.
- RESULT: flux head pressu total.

References:

Disclaimer: The aim of this technical tutorial is to illustrate various tools, modelling techniques and analysis workflows in DIANA. DIANA FEA BV does not accept any responsibility regarding the presented cases, used parameters, and presented results.