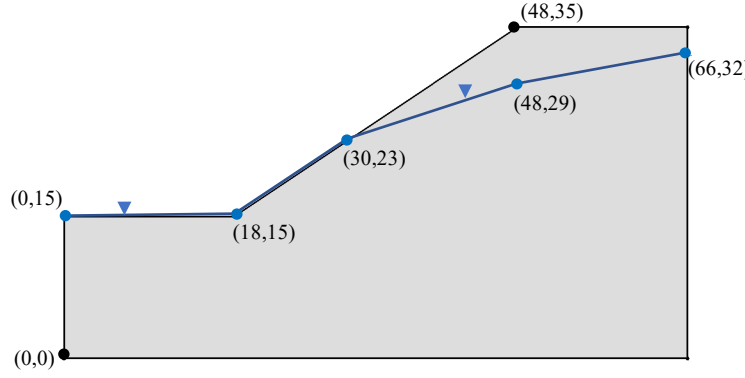
Simple Slope with Water Table

For LUSAS version:	24.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear

Problem Description

This overview example examines the stability of an embankment with a water table. The definition of the water table is covered in detail.



Problem geometry showing water table in blue

Keywords

2D, Plane Strain, Modified Mohr-Coulomb, Phi-c, Phreatic Surface.

Associated Files

Associated files can be downloaded from the user area of the LUSAS website.

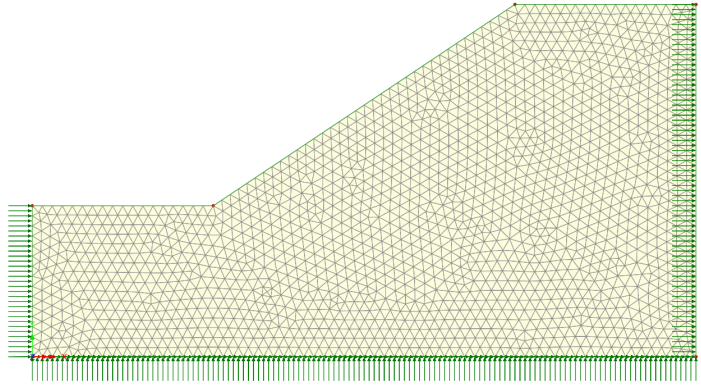
- **simple_slope_with_water_table.lvb** carries out automated modelling of the example.

  - Use **File > New** to create a new model of a suitable name in a chosen location.
  - Use **File > Script > Run Script** to open the lvb file named above that was downloaded and placed in a folder of your choosing.

Modelling overview

The model is meshed using two phase quadratic triangular plane strain elements (TPN6P). The bottom surface is fully restrained whilst the sides are allowed to displace vertically. A phreatic surface (as shown earlier) is prescribed within the domain with water pressure increasing linearly above and below it.

The following image shows the mesh and boundary conditions.



Mesh and boundary conditions

Material Properties

The soil properties are listed in Table 1.

Table 1: Material properties

Mass density	Young's modulus, E	Poisson's ratio, ν	Friction angle, φ^0	Dilation angle, ψ^0	Cohesion, c	Rankine stress, σ_1
1.918 t/m^3	50E3 kPa	0.4	15.0	0	41.65 kPa	150 kPa

Note that the Rankine stress is the Tensile cut-off value (as opposed to the compressive cut-off)

Table 2: Hydraulic properties

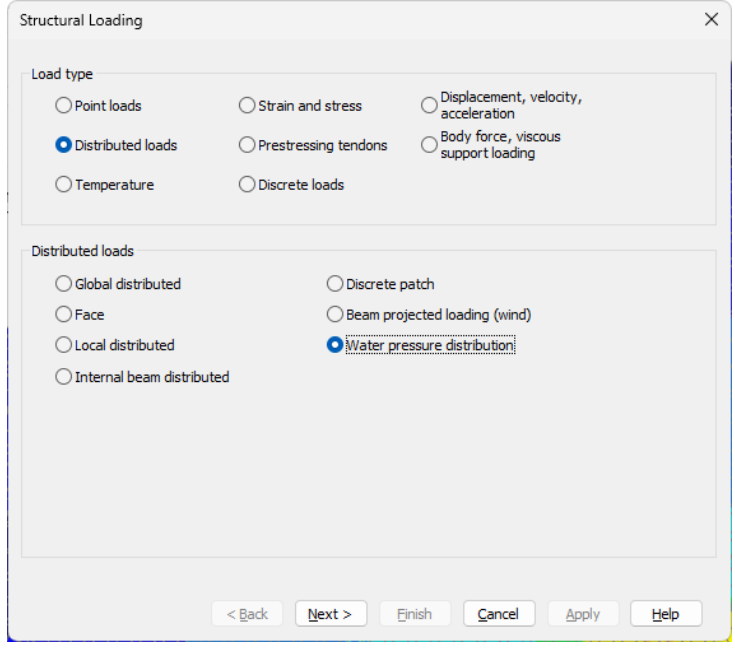
Bulk modulus of water	Porosity	Hydraulic conductivity	Density of water	Saturation at residual water content	Saturation at full water content
2.2E6 kPa	0.3	0.1 m/day	1.0 T/m^3	0.0	1.0

Loading Conditions

Gravity loading is applied.

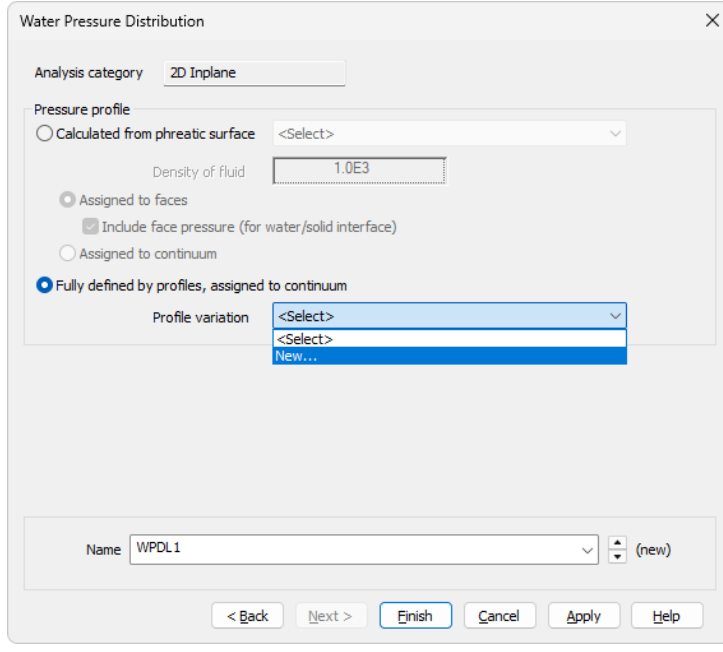
The pore water pressure distribution is generated from a 'Profile Variation'. A single profile relating water pressure to depth is assigned to each of the five points defining the linear segments shown in the Problem Geometry. The profile is extrapolated to cover the top and bottom of the problem domain.

The definition of the pore water pressure distribution is defined by selecting the **Attributes > Loading…** menu item, clicking the radio button **Distributed loads** and then **Water Pressure Distribution** followed by **Next >** .



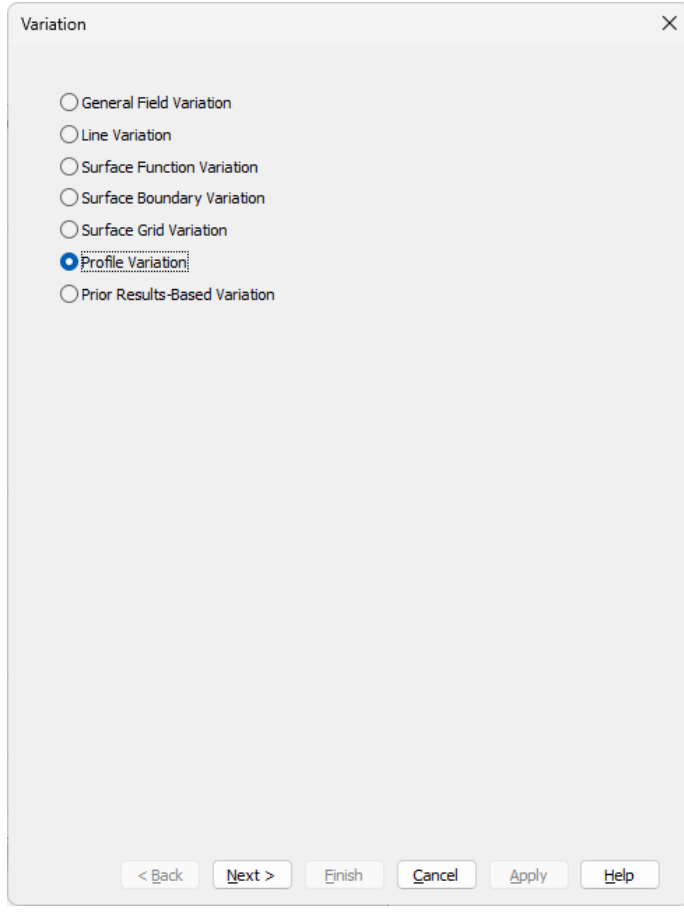
Structural loading dialog

On the resulting Water Pressure Distribution dialog, the radio button **Fully defined by profiles, assigned to continuum** is chosen. In the **Profile variation** dropbox the option **New…** is selected.



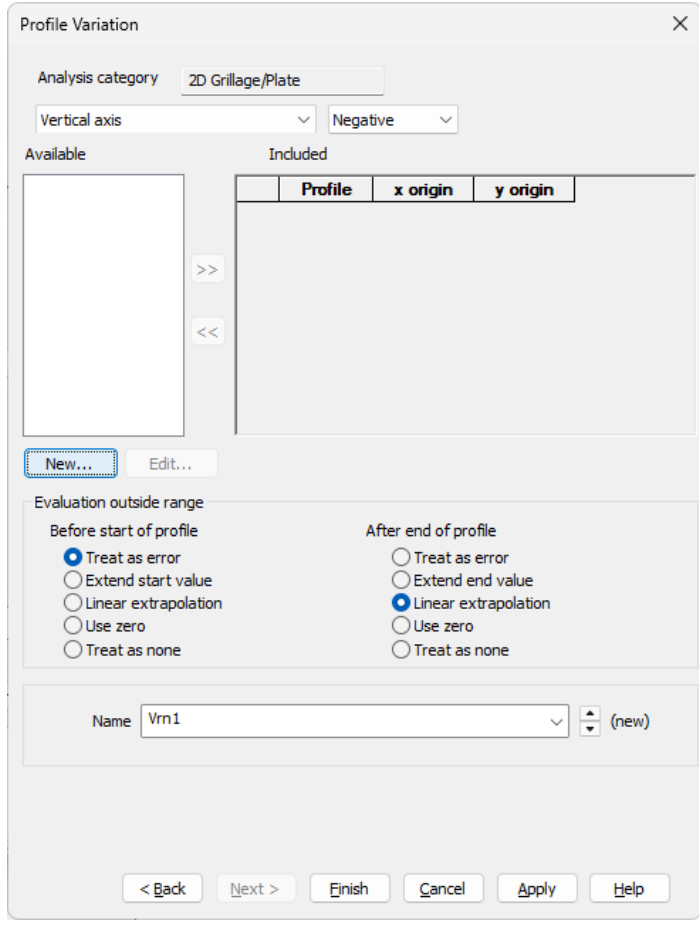
Water pressure distribution dialog

On the resulting Variation dialog **Profile variation** is chosen followed by **Next >.**



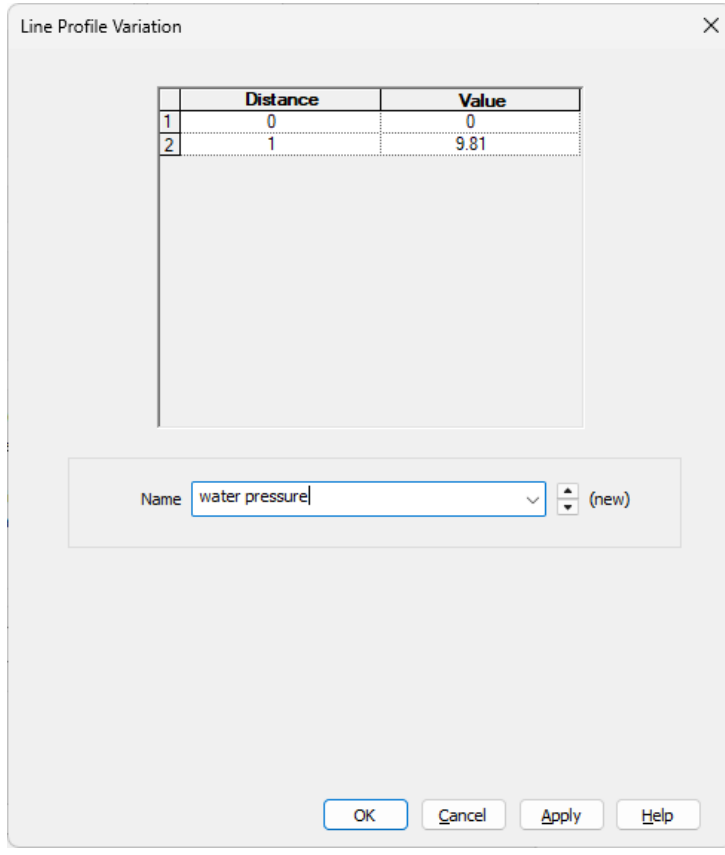
Variation dialog

On the Profile Variation dialog the button **New…** is pressed to define a new variation.



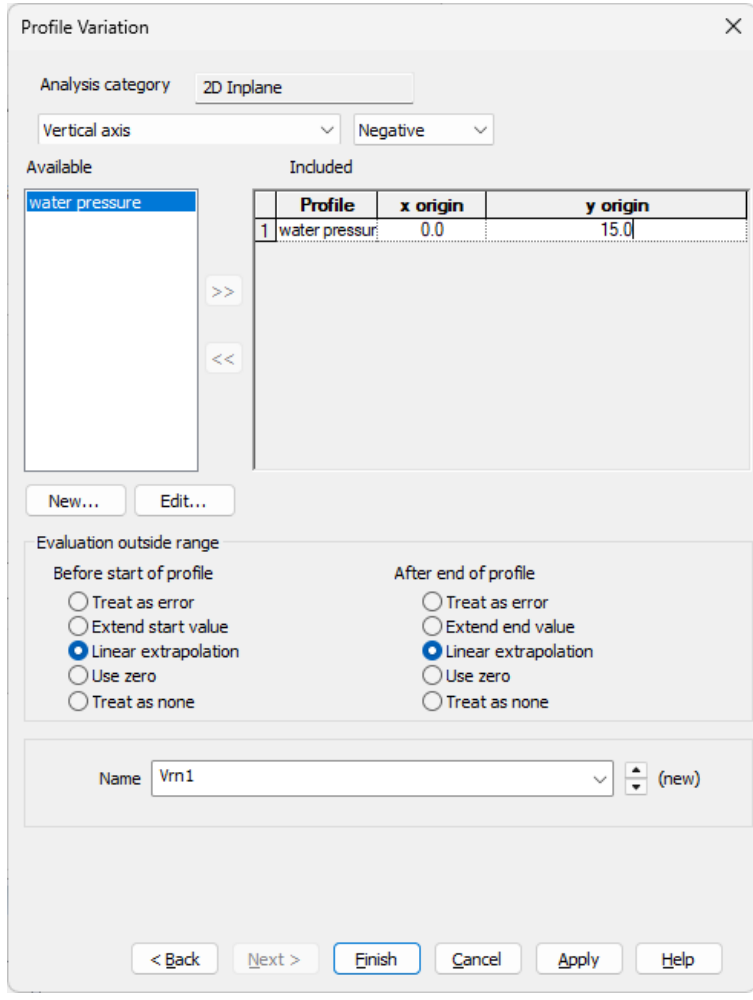
Profile variation dialog

On the resulting Line Profile Variation dialog values of (**0,0**) and (**1,9.81**) are defined (i.e. the pressure at 1m depth) and given a **Name** of 'water pressure' and **OK** pressed.



Line profile variation dialog

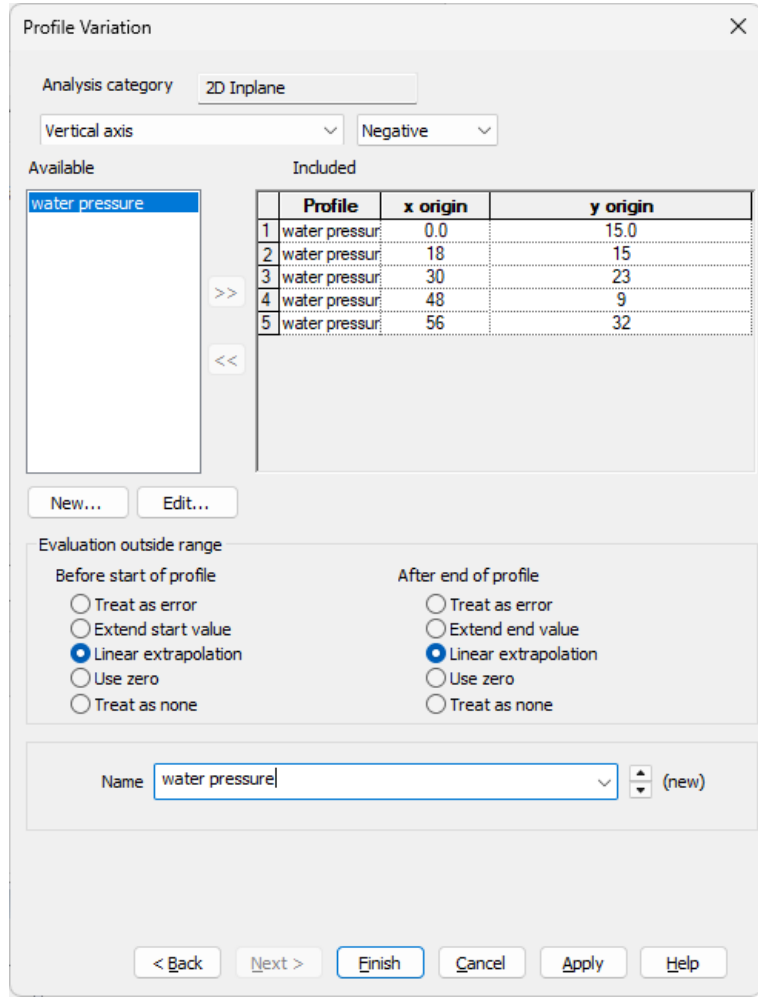
Back on the Profile Variation dialog ‘water pressure’ is added to the Included grid by pressing the ‘Add to’ button.



Select profile

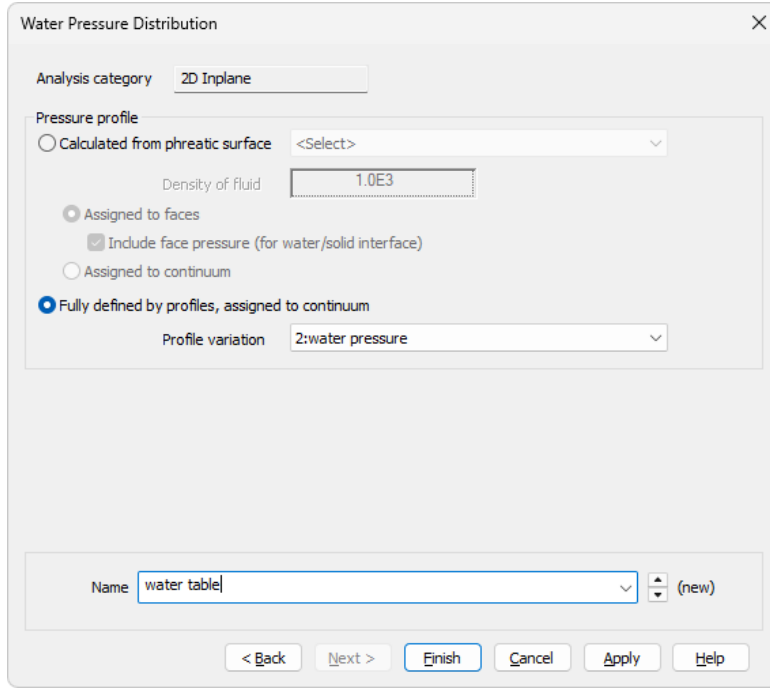
In the profile x and y origin fields enter (0,15) to mark the starting point of the profile. The radio button **Linear extrapolation** should be set in the **Before start of profile** section and should also be set in the **After end of profile** section.

Water pressure data should be added to the grid for each of the points (**18,15**), (**30,23**), (**48,29**) and (**66,32**). 'water table' is entered in the **Name** field and **Finish** pressed.



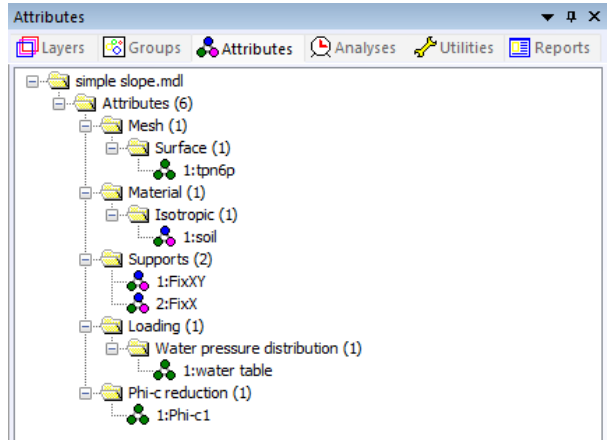
Water pressure distribution definition complete

Back on the Water Pressure Distribution dialog 'water table' is entered in the **Name** field and **Finish** pressed.



Water pressure distribution loading completed

The resulting water table load is added to the Attributes Treeview and then assigned to all surfaces in the model.



Water pressure load in Attributes treeview

In this example the Phi-c 'Minimum change in safety factor' (specified using the menu item **Attributes > Phi C Reduction**) is increased from 0.01 to 0.001 so that results obtained can be compared (at the end of the example) with those from other software, which are quoted to three decimal places.

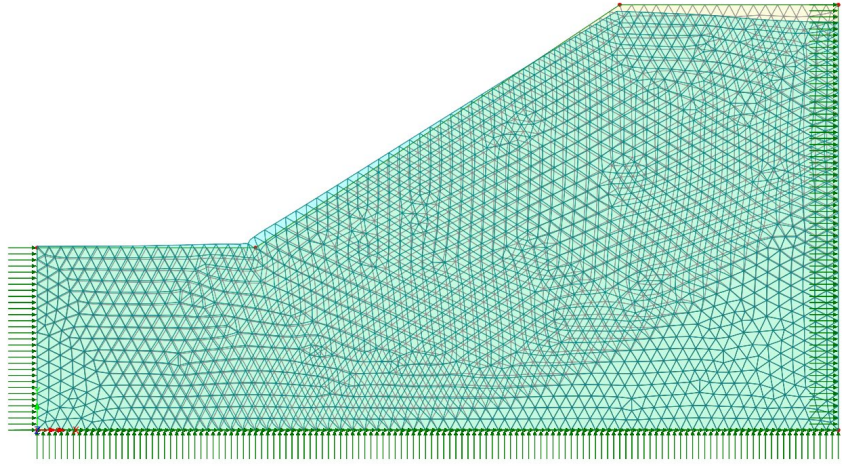
Running the Analysis

 Press **OK** to run the analysis.

Viewing the Results

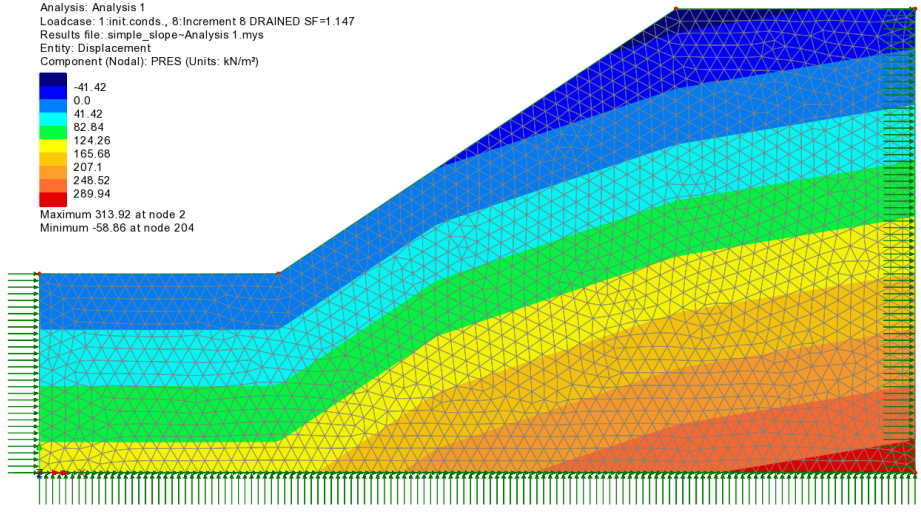
Analysis results are present in the Analyses  Treeview. The 'Initial conditions' loadcase will be set active.

- Turn off the display of the loading to see the following view of the model.



Pore water pressure distribution

- Turn off the geometry and deformed mesh layers.
- Add a contours layer to display entity **Displacement** and component **PRES**.

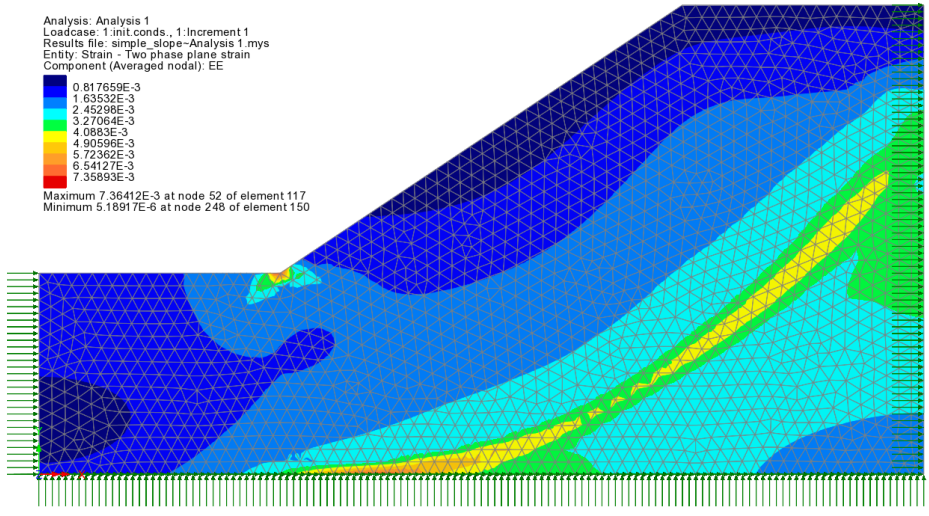


Pore water pressure distribution

Effective strain

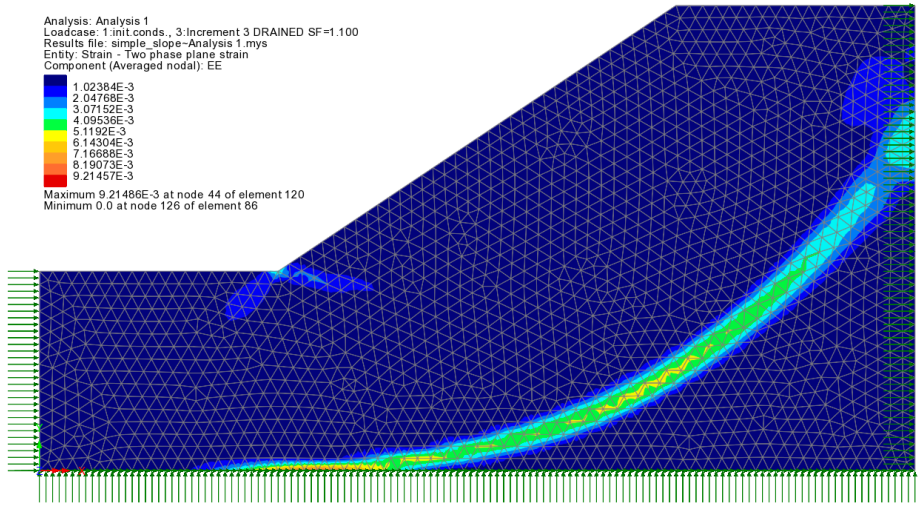
- Change the contours layer to show contours of entity **Strain – two phase plane strain** and component **EE**.

At the start of the phi-c analysis the slope is already showing signs of failure.



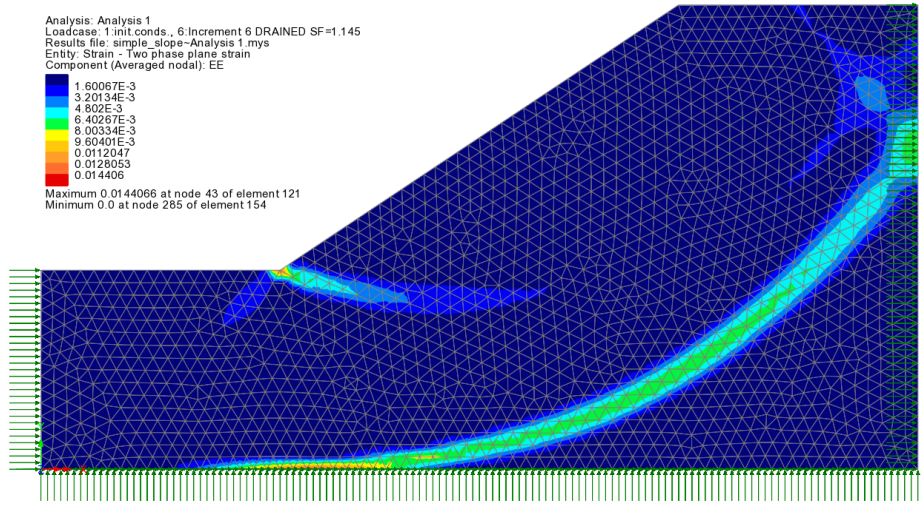
Effective strain at safety factor 1.0

At the safety factor SF=1.1 the failure surface is well established but failure is contained by the fixed boundary on the left-hand side.



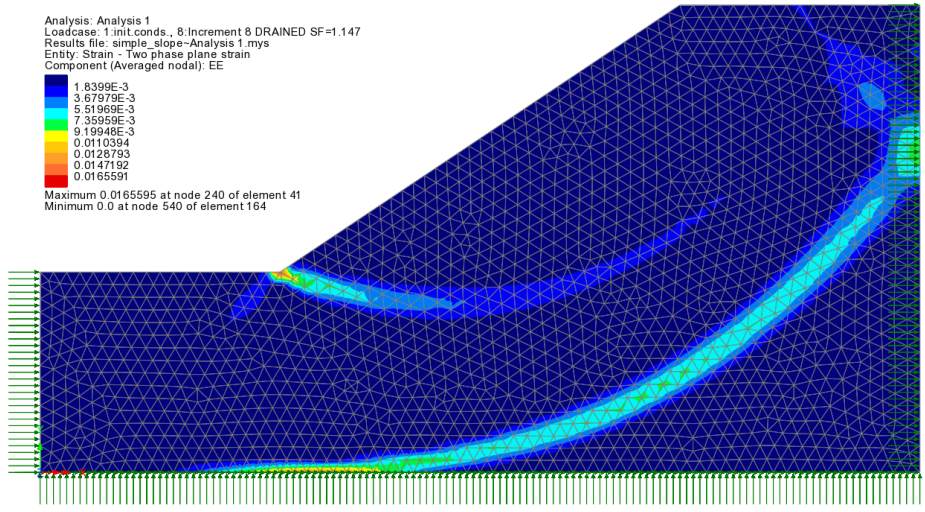
Effective strain at safety factor 1.1

At SF=1.145 the upper failure surface starts to form.



Effective strain at safety factor 1.145

At SF=1.147 the upper failure surface is nearly fully complete.



Effective strain at safety factor 1.147

Verification

Table 3 shows the factor of safety obtained compared to other methods, with LUSAS giving a slightly higher value.

Table 3: Factor of safety for different solution methods

Method	Factor of safety	
	Circular surface	Non-circular surface
Bishop	1.117	
Janbu simplified	1.046	
Janbu corrected	1.131	
Spencer	1.118	
RS2	1.09	
LUSAS Modified Mohr Coulomb	1.147	