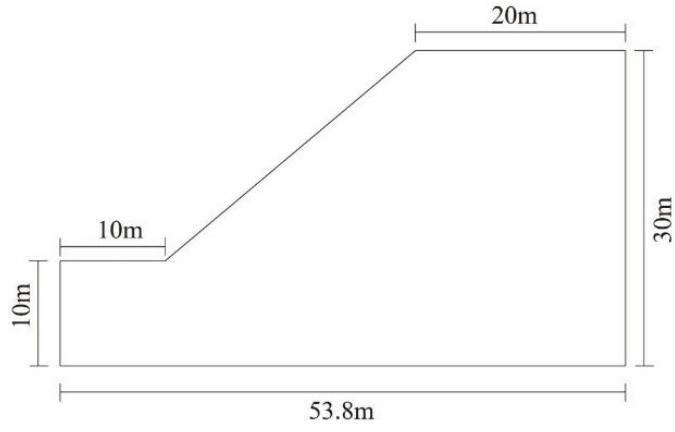
Influence of Rainfall on Slope Stability

For LUSAS version:	23.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear, Dynamic

Problem Description

The problem considered in this example considers the infiltration of water downward through a 20m high slope inclined at 40 degrees, with the water table located at the base of the slope.



Slope model

Keywords

Rainfall, Slope Stability, Piecewise Linear Definition of Draining/Filling Curve.

Associated Files

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

- ❑ **influence_of_rainfall_on_slope_stability.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.

Objectives

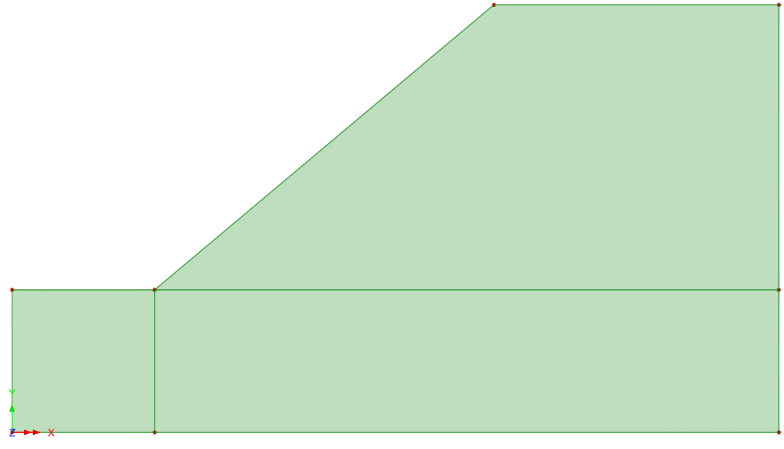
The objective is to analyse the stability of the slope, before and after the rainfall, through the calculation of the factor of safety.

Modelling overview

The model is created using an analysis category of **2D Inplane**, with model units of **kN,m,t,s,C**. The **Time Scale** is set to **Hours**.

Feature Geometry

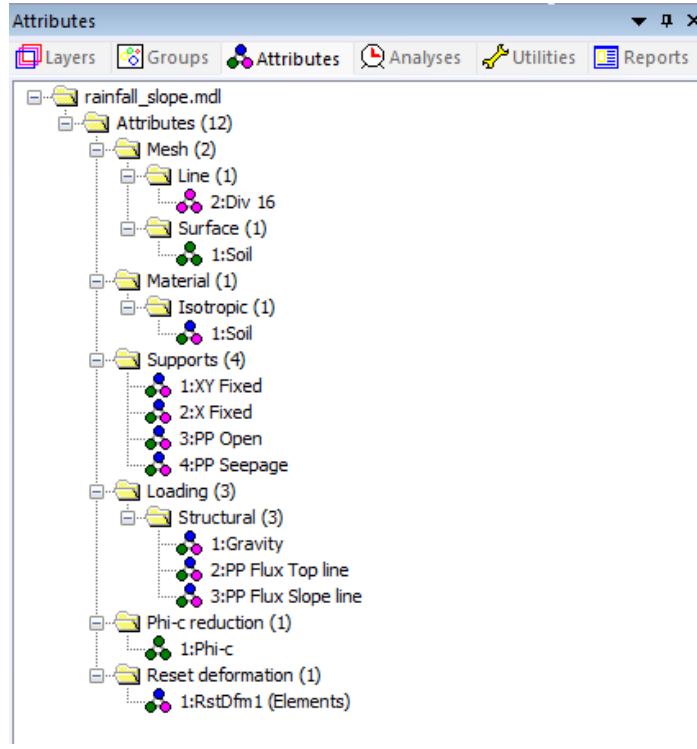
To build up the model, point and line features are used and then transformed into surfaces. To expedite the development of the model, it is recommended to utilise the **Copy** and **Sweep** commands. The feature geometry for the model is shown below.



Points, lines and surfaces defining model

Model Attributes

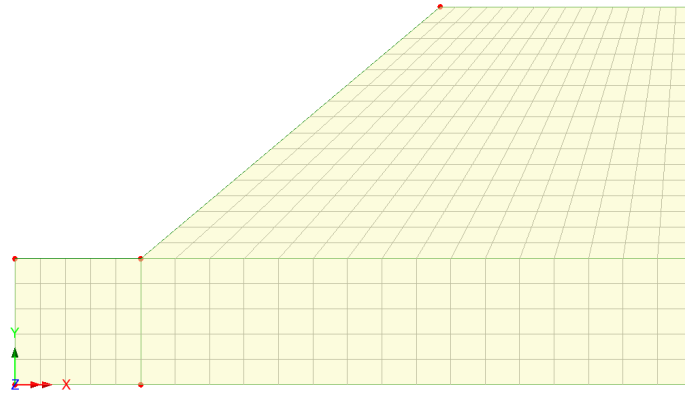
Model attributes (mesh, material, geometric properties, etc.) are defined and assigned to the model.



Model Attributes

Mesh

The slope is meshed using plane strain two phase, quadrilateral, quadratic elements (QPN8P) with an element size of 2m.



Model Meshing

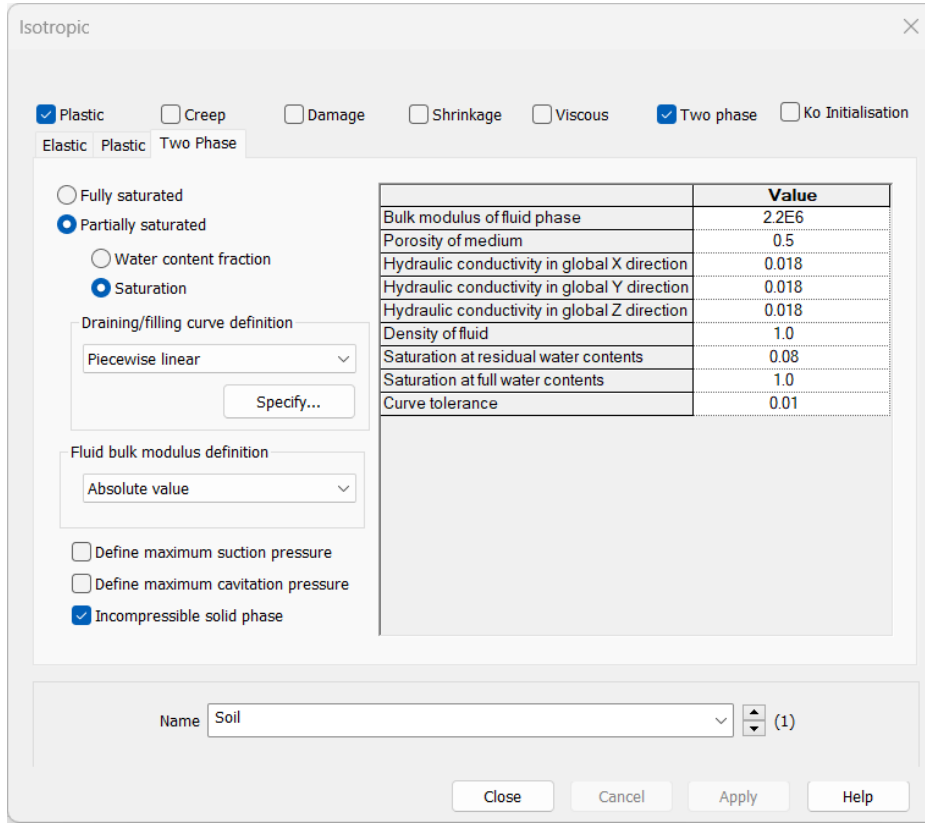
Materials

An isotropic nonlinear material utilising the Modified Mohr-Coulomb failure surface is used for the slope. Material properties are listed in Table 1.

Table 1: material properties

Layer	Soil grain density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Angle of dilation, ψ	Cohesion, c
Soil	1.8 t/m^3	100.0E3 kPa	0.3	30°	0º	15 kPa

The two-phase properties for the material are shown in the following dialog.



Two-phase properties for sand drains

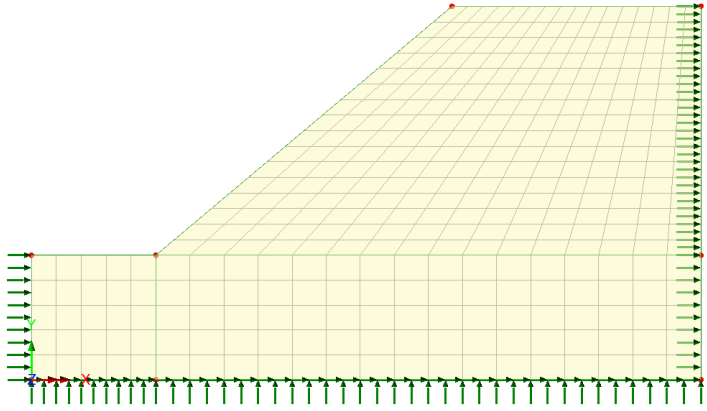
For a partially saturated soil, the **Draining/Filling Curve** is defined as follows:

Pore Pressure (kPa)	Relative Permeability	Effective Saturation
0.0	1.0	1.0
-20.0	0.983977	0.409885
-40.0	0.949753	0.123317
-60.0	0.904647	0.090867
-80.0	0.853322	0.084
-100.0	0.79924	0.081836
-120.0	0.744902	0.080971
-140.0	0.692013	0.080566
-160.0	0.641653	0.0805
-180.0	0.594431	0.080355
-200.0	0.550626	0.080235
-220.0	0.510292	0.080163
-240.0	0.473339	0.080116
-260.0	0.439592	0.080086

Pore Pressure (kPa)	Relative Permeability	Effective Saturation
-280.0	0.408831	0.080065
-300.0	0.380815	0.080039
-320.0	0.355304	0.080031
-340.0	0.332063	0.080025
-360.0	0.310874	0.080021
-380.0	0.291533	0.080017
-400.0	0.273855	0.080014

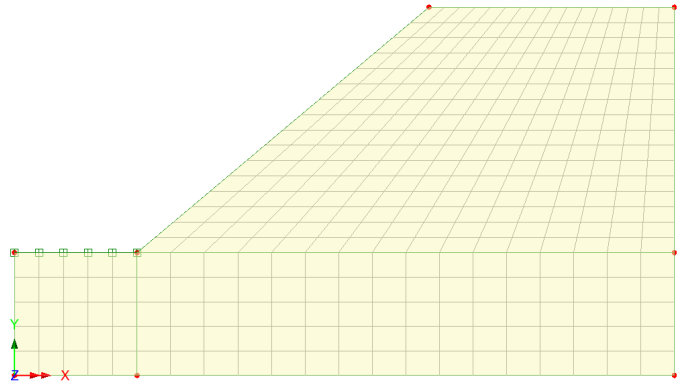
Supports

The base of the model is constrained in both X and Y directions, while the lateral sides are limited only in the X direction.



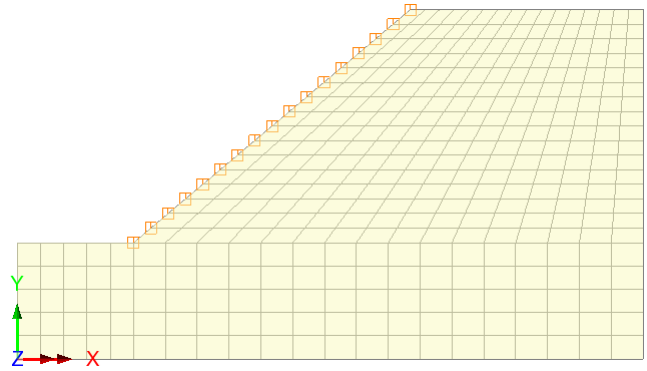
Boundary conditions at initial stage

To establish the position of the phreatic surface, the pore pressure is set to **Open** and assigned to the upper horizontal line on the left of the model (line 3) as shown on the following image.



Phreatic surface boundary conditions

Pore pressure is set to **Seepage** and assigned to the inclined face of the slope.



Pore pressure set to Seepage

Loads

The following load are considered in the analysis

- Gravity
- Pore pressure flux applied to the top and inclined face of the slope.

Other Attributes

Two other attributes are required to be defined in the analysis: **Phi-c Reduction** which calculates the factor of safety of the slope and **Reset Deformation** to reset the displacement in the initial phase of the calculation.

Analyses considered

Analysis 1

Initial Phase

This stage establishes the initial stress and water pressure distributions with gravity acting as a load and the model being restricted from movement at the base and sides.

Nonlinear analysis control properties are defined for this phase, all the parameters are left at their default values.

Branch Analysis - Stability

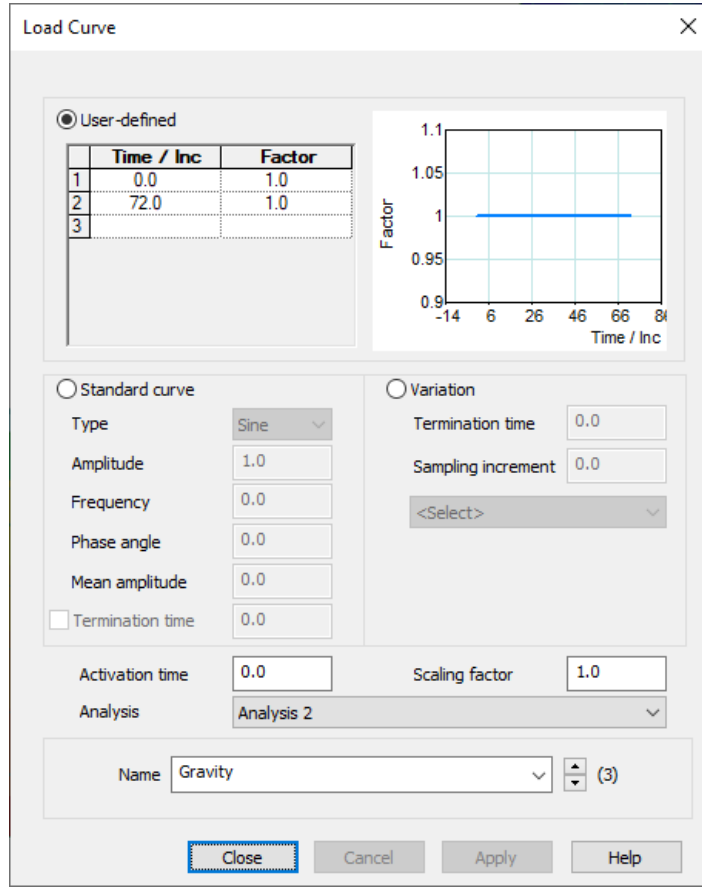
In this phase we calculate the factor of safety of the slope.

Analysis 2

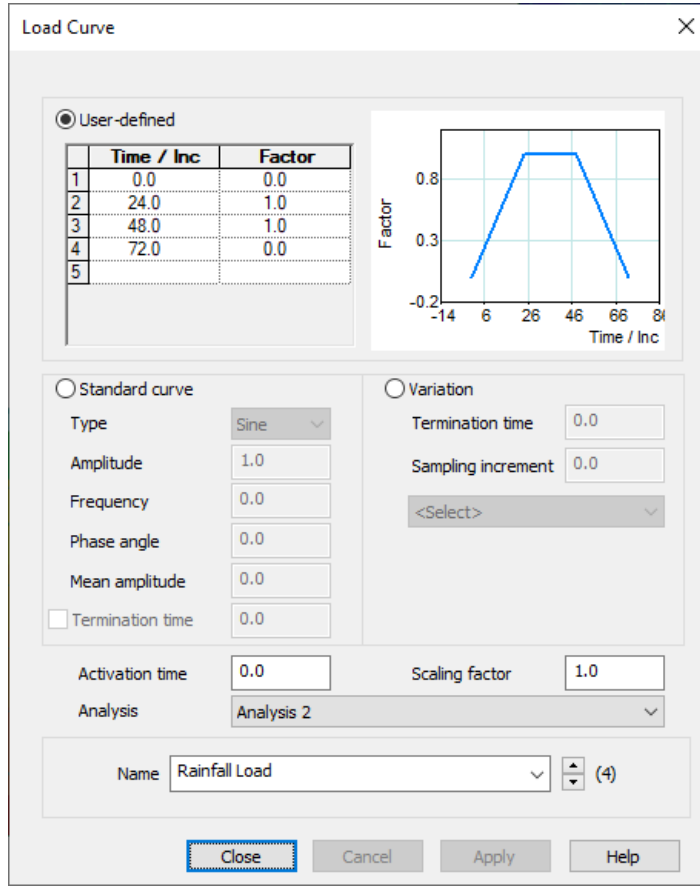
Rainfall

In analysis 2, we simulate the water infiltration downward through the soil due to rainfall, for this purpose we first create a Load Curve by the command **Analysis2 (right click) > New > Load Curve**.

Using load curves, we assign the gravity load and the change of pore pressure flux over the total period of 72 hours.

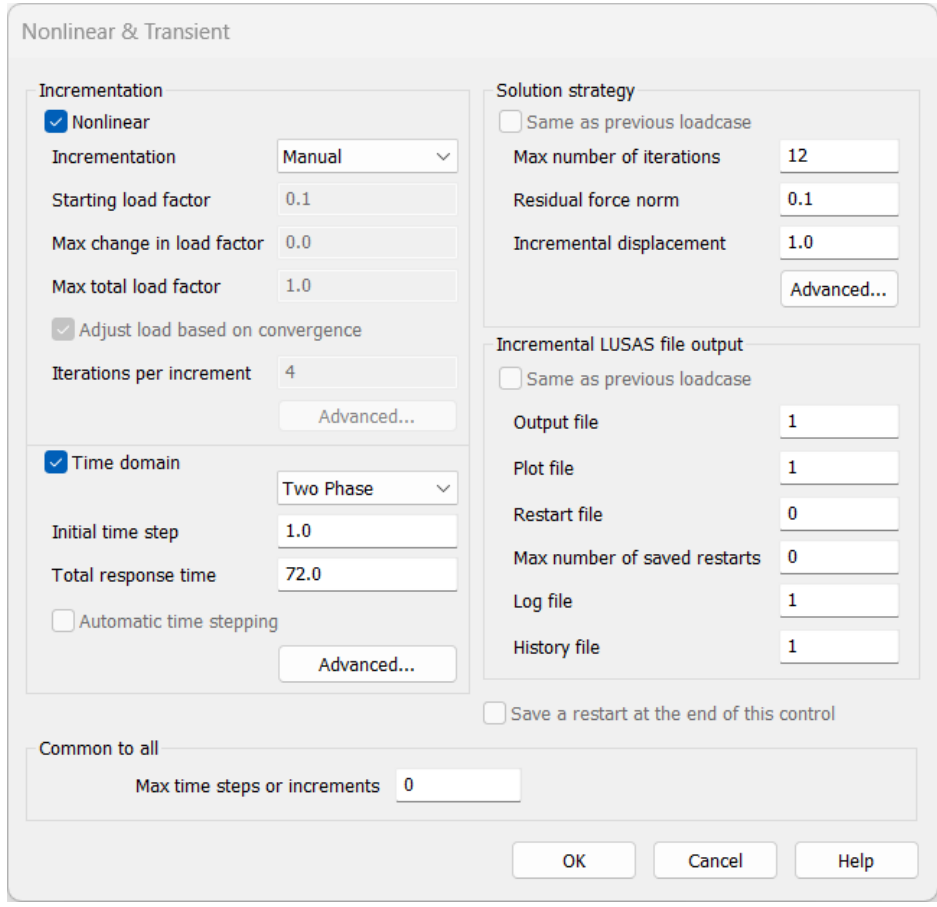


Load curve for gravity as used in analysis 2



Load curve for rainfall loading as used in analysis 2

Nonlinear analysis control properties are set as shown below. The total response time is set to 72 hours with a time step of 1 hour.



Nonlinear analysis control parameters

Branch Analysis - Stability

We calculate the factor of safety of the slope after the rainfall.

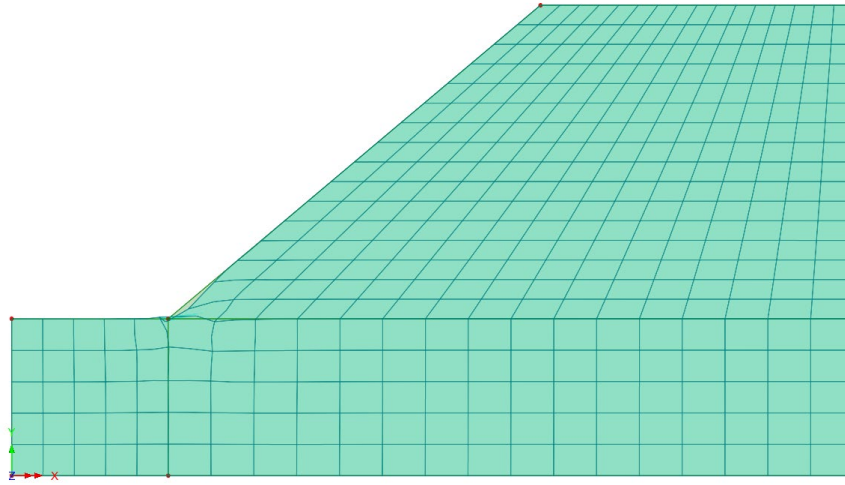
Running the Analysis

Ensure all analyses are selected and press **OK** to run the analysis.

Viewing the Results

Analysis loadcase results are present in the Treeview.

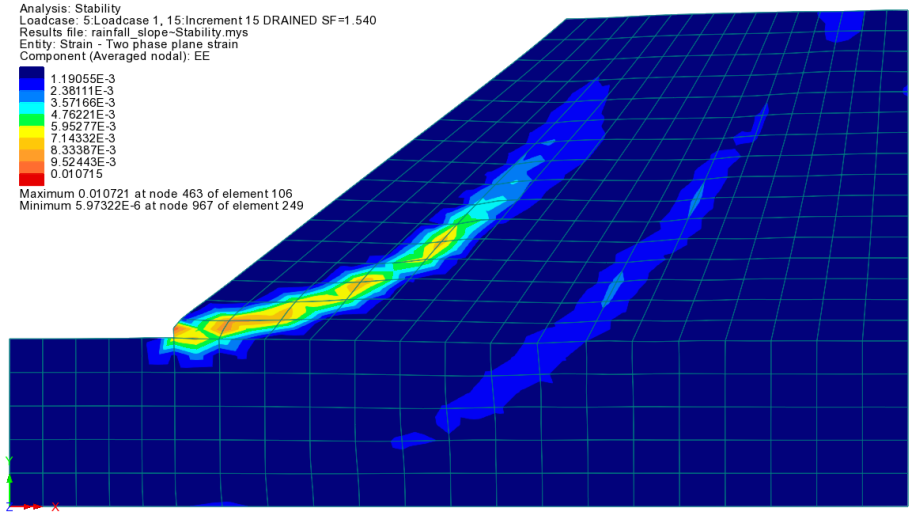
- Turn off the geometry and mesh layers and supports and loading to give this view.



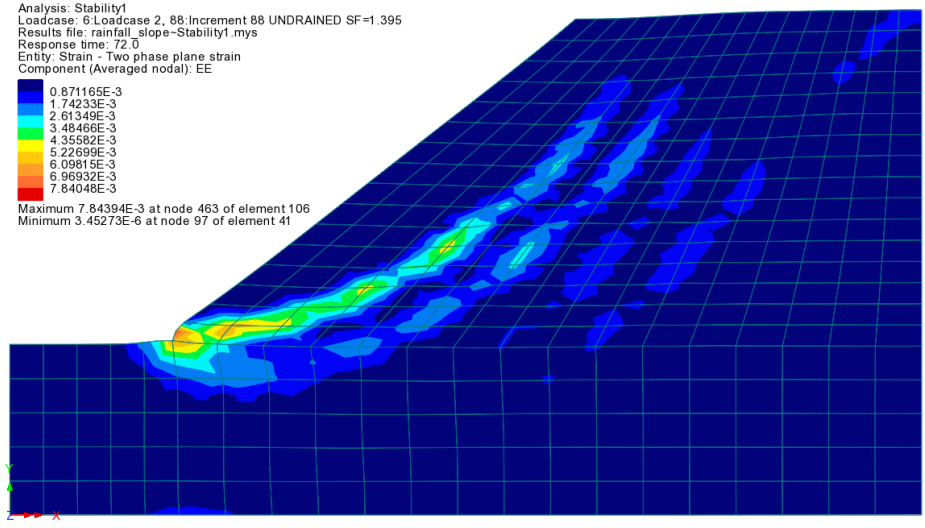
Factor of Safety

- Add the contours layer to plot contours of entity **Strain – Two phase plane strain** and component **EE**

The shear zone resulting before and after rainfall is shown in the following images, with factor of safety values of 1.54 and 1.40 for final load increments in Analysis 1 and Analysis 2 respectively.



Shear zone at failure before rainfall



Shear zone at failure after rainfall