Influence of Rainfall on Slope Stability

For LUSAS version:	22.0
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 involves the infiltration of water downward through the slope body. Figure 1 illustrates the entire model, which consists of a 20-meter-high slope inclined at 40 degrees, with the water table located at the base of the slope.

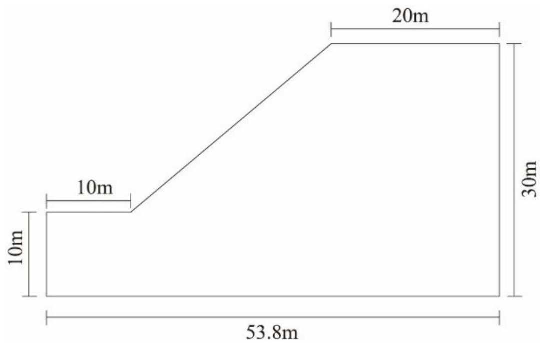


Figure 1: Slope model

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.mdl** is the model file for this example.

- Use **File > Open** to open the 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.

Preparing the Model Features

The user has to create a new model, set the Analysis category as 2D, and specify the model units as kN,m,t,s,C. The **Time Scale** is set to **Hours**.

Feature Geometry

To build up the model, point and line features can be utilized and then transformed into surfaces. To expedite the development of the model, it is recommended to utilise the **Copy** and **Sweep** commands. It is important for the user to ensure that the boundaries are properly connected and that there is no accidental overlap. The full model is depicted in Figure 2.

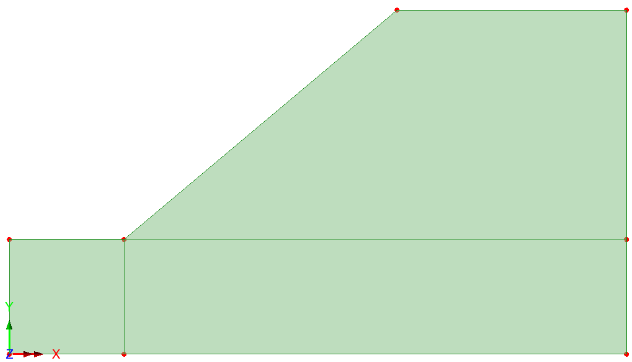


Figure 2: Slope model

Preparing the Model Attributes

Model attributes (mesh, material, geometric properties, etc.) are defined and assigned to the model. Figure 3 shows the attributes of model.

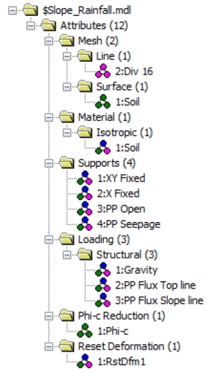


Figure 3: Model Attributes

Defining the Mesh

The slope is meshed using plane strain two phase, quadrilateral, quadratic elements (QPN8P) with an element size of 2m, (figure 4).

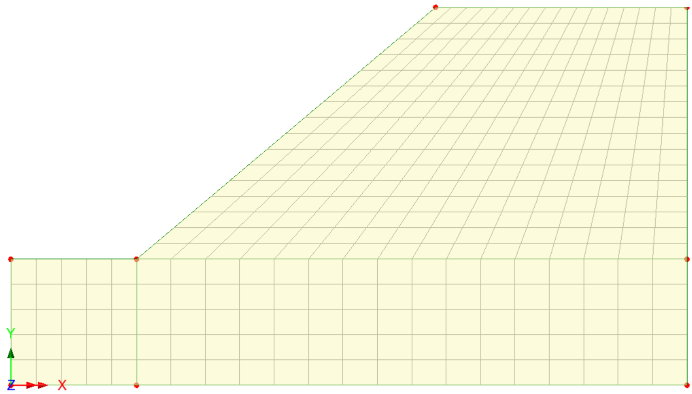


Figure 4: Model Meshing

Defining the Materials

An isotropic nonlinear material utilising the Modified Mohr-Coulomb failure surface is used for the slope. Material properties are listed in table 1. Figure 5 gives the two-phase properties for the material.

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

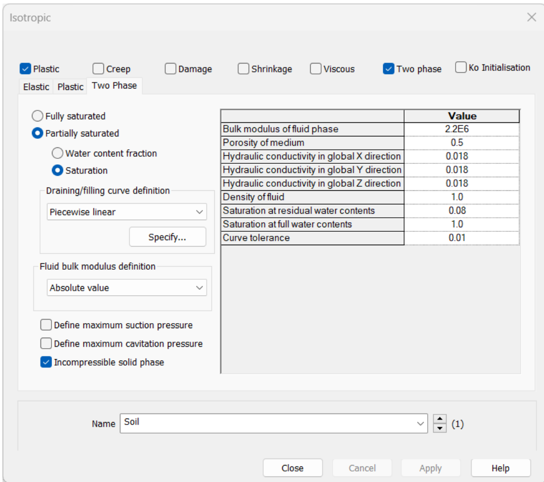


Figure 5: Two-phase properties for sand drains

For a partially saturated soil, we define the **Draining/Filling Curve** 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
-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

Defining the 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 (Figure 6).

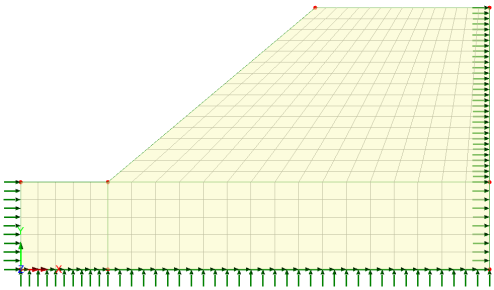


Figure 6: Boundary conditions at initial stage

- To establish the position of the phreatic surface, the pore pressure is set to **Open** at line 3 as shown in figure 7.

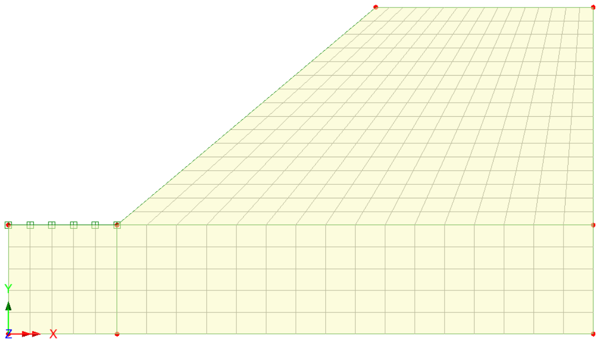


Figure 7: Phreatic surface boundary conditions

- Pore pressure is set to **Seepage** and assigned to the inclined face of the slope as per figure 8.

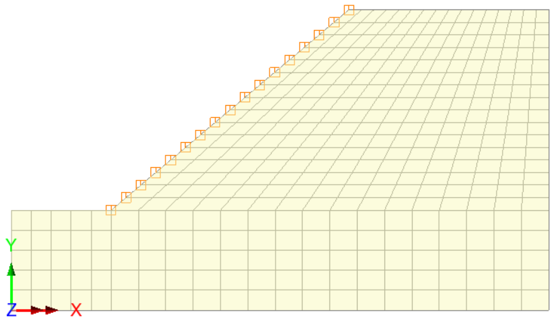


Figure 8: Pore pressure set to Seepage

Defining the Loads

The following load are considered in the analysis

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

Defining Other Attributes

We define two more attributes in the analysis: the **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.

Running the Analysis

We consider the following analyses and stages.

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 as shown in figure 6.

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

Analysis 1 > 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 (Figure 9).

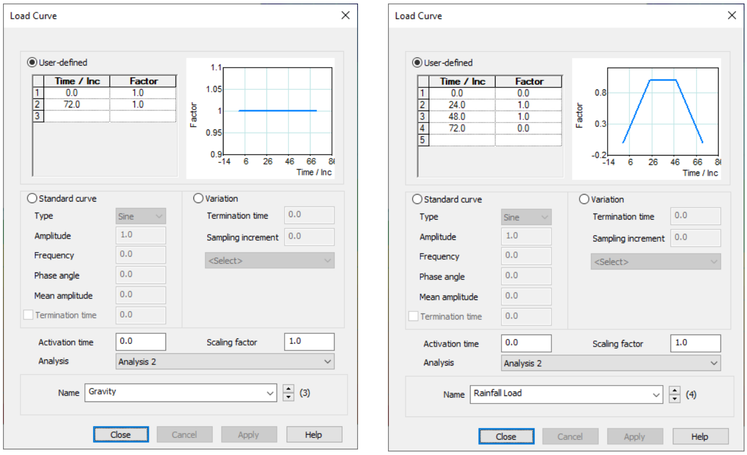


Figure 9: Load curves used in analysis 2

Nonlinear analysis control properties are set as shown in figure 10. The total response time is set to 72 hours with a time step of 1 hour.

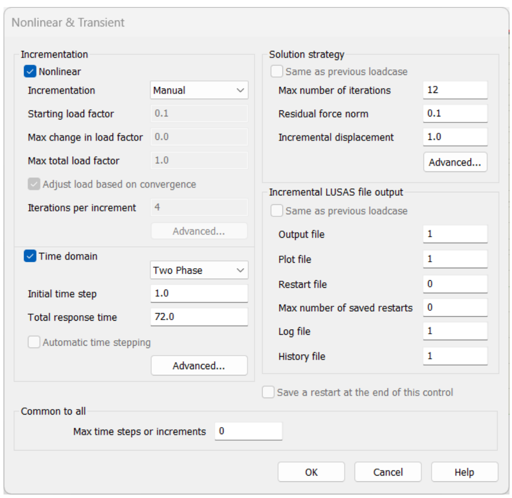


Figure 10: Nonlinear analysis control parameters

Analysis 2 > Branch Analysis - Stability

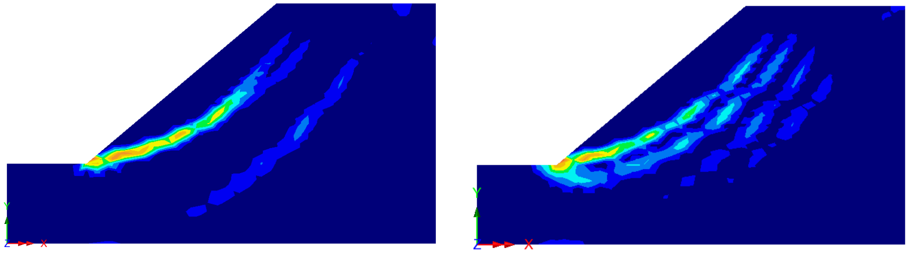
We calculate the factor of safety of the slope after the rainfall.

Viewing the Analysis

Analysis loadcase results are present in the Treeview.

Factor of Safety

The shear zone resulting from rainfall is depicted in figure 11, with factor of safety values of 1.54 and 1.40 for the two cases, respectively.



Before rainfall After rainfall

Figure 11: Shear zone at failure