Modelling of Wick Drains

For LUSAS version:	21.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear, Dynamic

Problem Description

Wick drains accelerate the settlement process of embankments built on soft soils by providing channels for water to drain quickly away, improving the overall stability of the embankment. This technique is demonstrated through the application of a wick drainage system in a 1.4-metre-high road embankment (Figure 1).

Keywords

Wick Drains, Pore Pressure, Nonlinear Transient, Settlement, Two Phase Materials, undrained loading, automatic time stepping.

Associated Files

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

❑ **wick_drains.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 output of this example is the following:

❑ Calculating embankment settlement.

- ❑ Finding pore pressure distribution immediately after application of the load.
- ❑ Finding pore pressure dissipation with time at the centre of the embankment.

Preparing the Model Features

We create a new model, set the Analysis category as 2D, and specify the model units as kN,m,t,s,C. Timescale is set to **Days**

Feature Geometry

The model can be created by either using surface features directly, or through point and line features which are subsequently converted into surfaces. The **Copy** command is of considerable help in this case. It is important to ensure proper connection between surfaces and avoid any unintentional overlapping. Figure 1 shows the surfaces used to define this problem. The water table lies at the ground surface.

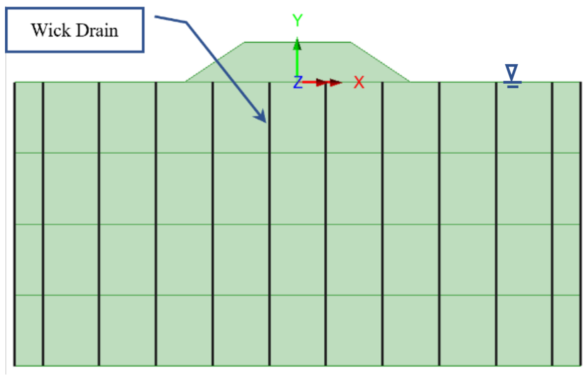


Figure 1: Geometry

Preparing the Model Attributes

Model attributes (mesh, material, geometric properties, etc.) are defined and assigned to the model. (Figure 2).

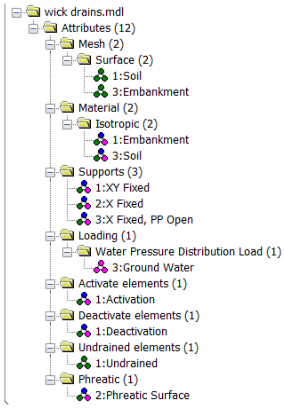


Figure 2: Model Attributes

Defining the Mesh

The soil is meshed using plane strain, two phase, quadrilateral, quadratic elements (QPN8P), whereas the embankment is meshed with plane strain, quadrilateral, quadratic elements (QPN8) as illustrated in figure 3.

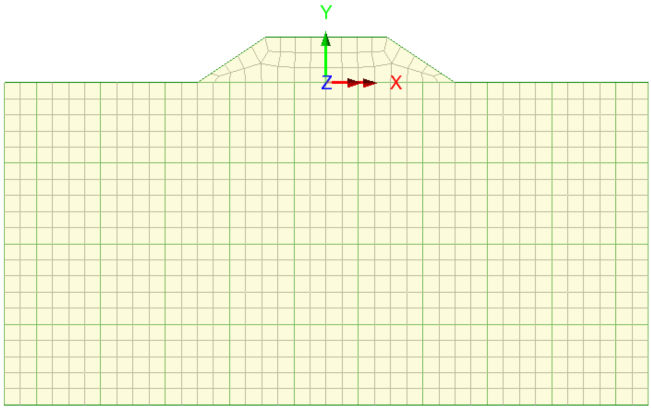


Figure 3: Model meshing

Defining the Materials

An isotropic elastic material will be used for the embankment whilst an isotropic nonlinear material utilising the Mohr-Coulomb failure surface will be used for the soil. The initial stress state in the soil is defined by the coefficient of lateral earth pressure, K_0.

Table 1 gives the material properties adopted in the example.

Table 1: Soil material properties

Layer	Mass Density	Young's modulus, E	Poisson's ratio, ν	Angle of friction, φ	Angle of dilation ψ	Cohesion, c	Earth pressure coefficient, K_0
Embankment	2 t/m^3	100E3 kPa	0.3	-	-	-	1.0
Soil	1.8 t/m^3	15E3 kPa	0.3	25°	25°	15 kPa	0.5

The properties of the soil are assigned as two-phase material properties when analysing the soil in both drained and undrained states. Figure 4 shows the chosen properties and options. It is important to note that as the timescale was chosen to be days that the hydraulic conductivity is also given in units of metres per day.

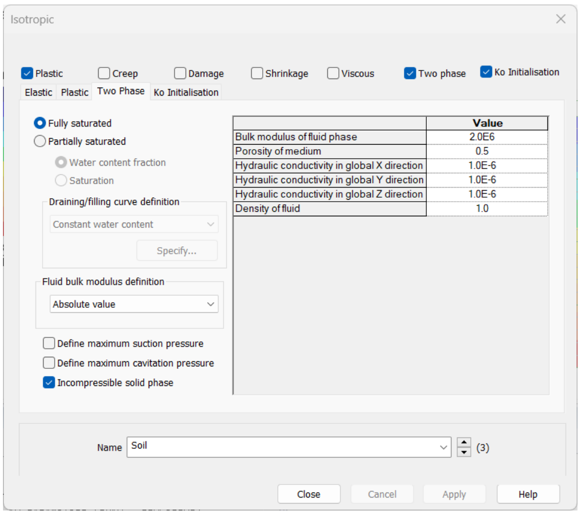


Figure 4: Two-Phase properties

Defining the Supports

- Fully fixed supports are assigned to the base, while the lateral sides are fixed in the horizontal direction as shown in the figure 4.
- The left point is fixed in the X direction and additionally the pore pressure is set to **Open** (Figure 5). During the groundwater initialisation step, this will set the hydrostatic porewater pressure at the point to zero.

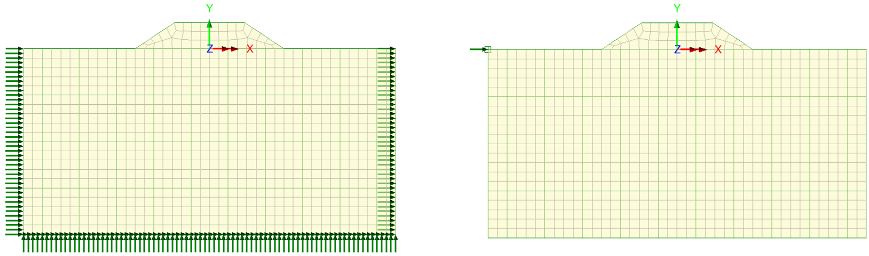


Figure 5: Boundary conditions

Defining the Loads

To keep a permanent hydrostatic pressure in the Wick drains, a phreatic surface is created. A line on the left of the model marks the level of the phreatic surface (Figure 6). Then using **Attributes > Pore Water Pressures > Phreatic Surface**, a phreatic surface attribute is created which is assigned to the line. The phreatic surface is then linked to a **Water Pressure Distribution** attribute created through the command **Attributes > Loading > Water Pressure Distribution** (Figure 7). This attribute is then assigned to the lines representing the Wick drain and also to the ground surface.

Self-weight can be added to any load case by right-clicking on the load case in the Treeview and selecting **Gravity**.

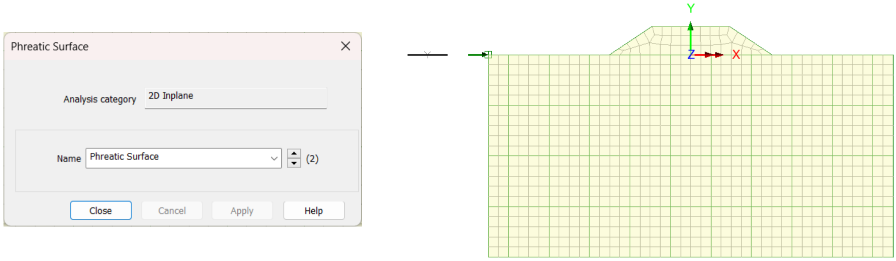


Figure 6: Phreatic Surface

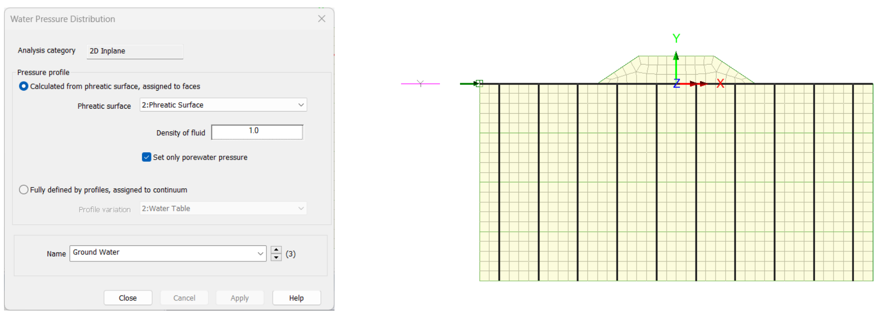


Figure 7: Water Pressure Distribution

Defining Other Attributes

In addition to the previous attributes, additional attributes need to be defined:

- Activate and Deactivate
- Pore Pressure > Undrained

During the simulation of the construction stages, we have to deactivate and then activate the embankment whilst an **undrained** attribute is required in the undrained phase. More clarification is found in the following paragraphs.

Running the Analysis

The following modelling and loading phases are considered.

Initial Phase

In this phase, the embankment has not yet been constructed, so it is deactivated using the command **Deactivate** (Figure 8). The Pore Pressure Open is included in this phase to establish a hydrostatic pore pressure distribution in the soil beneath the embankment.

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

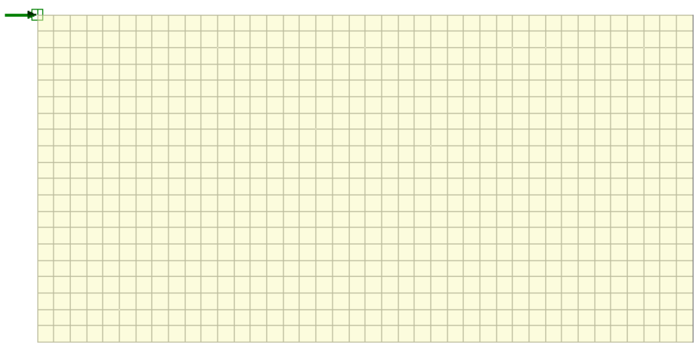


Figure 8: Initial phase

Undrained Loading

The embankment is activated using the attribute **Activate** (Figure 9), it acts as a surcharge to the original ground surface. This surcharge will increase pore water pressures initially, that are slow to dissipate due to the low permeability of the soil, but with time the water will drain away, and the soil voids will compress.

The soil underlying the embankment is defined as an undrained region by assigning the **Undrained** attribute, with the increase in stress carried predominately by the pore water with little new stress carried by the soil skeleton.

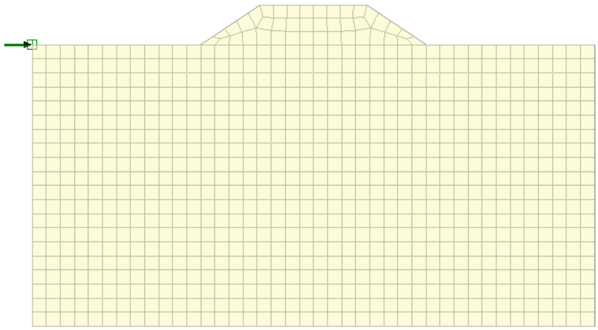
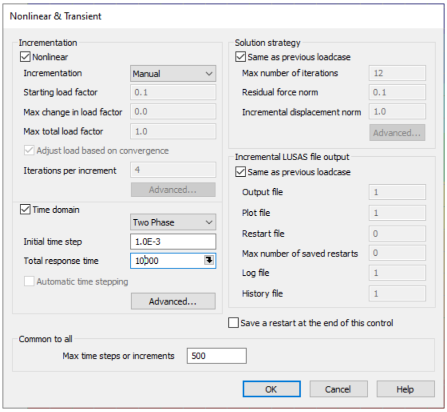


Figure 9: Construction of the embankment in phase 2

Drained Loading

The Wick drains are used to shorten pore water travel distance and thus accelerate primary settlement. Pore water will flow laterally to the nearest drain, as opposed to vertical flow to an underlying or overlying drainage layer. In this analysis, we assume the Wick drains are full of water at atmospheric pressure by assigning the attribute **Water Pressure Distribution** (Figure 7).

Nonlinear analysis control properties are defined for this phase. The following is selected **Time domain > Two Phase**, the adopted values are given in the figure 10. Automatic time stepping is used with a target change in pore water pressure of 1kPa for each step and a termination value of the maximum pressure difference of 0.001 kPa from the steady state value. The initial time step is 0.001 days whilst the maximum timestep is limited to 100 days.



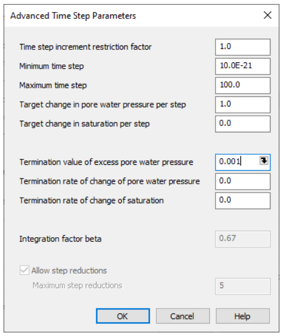


Figure 10: Nonlinear analysis control parameters

Viewing the Analysis

Analysis loadcase results are present in the Treeview.

Pore Pressure

The distribution of pore pressure for the three stages are shown in the figure 11. It clearly illustrates the generation of the excess pore pressures and their dissipation with time. The variation of pore pressure at A over time is plotted in figure 12.

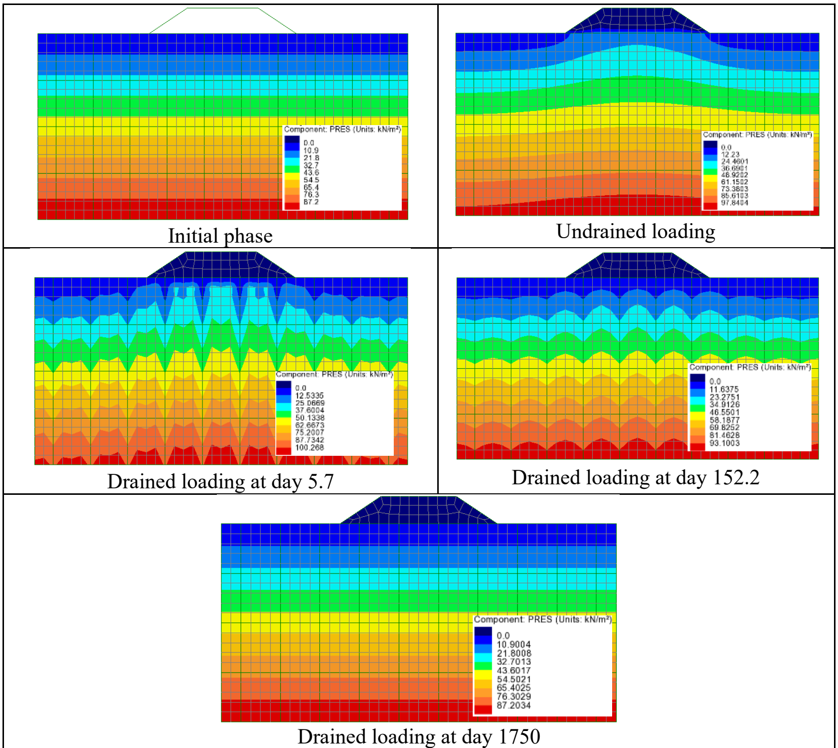


Figure 11: Pore Pressure with time

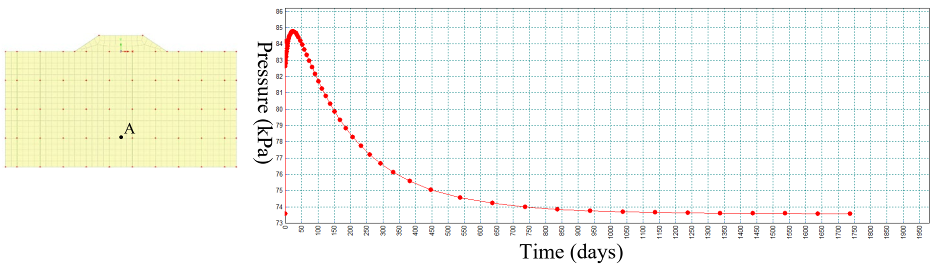


Figure 12: Variation pore pressure with time at point A

Settlement

Figure 13 shows the settlement beneath the embankment at point B which after 1750 days is 9 mm.

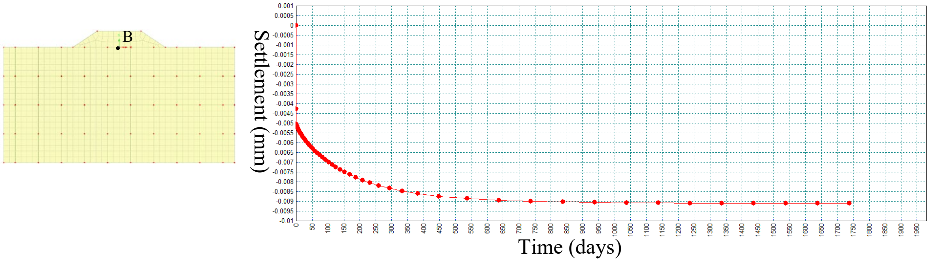


Figure 12: Settlement at point B