Simple Slope with Water table

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

Problem Description

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

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.

Discretisation

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 is prescribed within the domain with water pressure increasing linearly above and below it. Figure 1 shows the problem geometry and Figure 2 the 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, v	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

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

Table 2: hydraulic properties

Loading Conditions

Gravity loading is applied.

Modelling Hints

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 figure 1. The profile is extrapolated to cover the top and bottom of the problem domain. The definition of the pore water pressure distribution is detailed in the following.

From Attributes > Loading... click the radio button Distributed loads and then Water Pressure Distribution followed by Next> (figure 3).

Structural Loading	\times
Load type O Point loads O Strain and stress O Displacement, velocity, acceleration, body force O Temperature O Discrete loads	
Distributed loads O Global Distributed O Face Discrete patch O Face Deam projected loading (wind)	
O Local Distributed O Internal Beam Distributed	
<back next=""> Enish Cancel Apply Help</back>	

Figure 3: Structural loading dialog

Click the radio button **Fully defined by profiles, assigned to continuum** (figure 4). Then click the arrow in the **Profile variation** dropbox and click on **New...**

Water Pressure Dis	tribution			
Analysis category	2D Inplane			
Pressure profile				
O Calculated fro	mphreatic surface	L:ground water		\sim
		1.0	-	
	Density of fluid	1.0		
Assigned	o faces			
🗹 Includ	face pressure (for wa	iter/solid interface)		
O Assigned	o continuum			
Contradiction of the				
O Fully definited i	ry pronies, assigned to	continuum		
	Profile variation	<select></select>		\sim
	((Select)		
	Ľ			
	at a set of the			
Name	ater table			(new)
	Rack	Next	Cancel	Apply Help

Figure 4: Water pressure dialog

On following dialog select **Profile variation** and click **Next>** (figure 5).



Figure 5: Variation dialog

On the **Profile Variation** dialog click on **New...** to define a new variation (figure 6).

Analysis category 2D Inpl	ane			
Vertical axis	✓ Nega	tive 🛛 🗸 🗸		
Available	Included			
	Profile	x origin	y origin]
>>				
<<				
New Edit				
New Edit				
New Edit Evaluation outside range Before start of profile		After end of pro	ofile	
New Edit Evaluation outside range Before start of profile © Error		After end of pro	file	
New Edt Evaluation outside range Before start of profile © Error © Extend start value Q Linear extrapolation		After end of pro OError OExtend e OLinear ex	ofile and value strapolation	
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New Edt Evaluation outside range Before start of profile © Error Extend start value Linear extrapolation Name [Vm1]		After end of pro OError OExtend e OLinear ex	ofile and value ctrapolation	• (new)
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Figure 6: Profile variation dialog

In the line variation dialog enter (0,0) and (1,9.81) (ie the pressure at 1m's depth). In the **Name** field enter 'hydrostatic pressure' and then click **OK** (figure 7).

Line Profile	Variation	×
	Distance Value 1 0 0 2 1 9.81	
	Name [hydrostatic pressure] v 🐑 (new)	
	OK Cancel Apply Help	

Figure 7: Line variation dialog

Now click 'hydrostatic pressure' followed by the double chevrons >> (figure 8).

Vertical axis	✓ Ne	gative ~	
Available	Included		
hydrostatic pressure	Profile	x origin	y origin
New Edit			
Evaluation outside range			
Before start of profile		After end of pro	ofile
Error		OError	
C Linear extrapolation		 Extend e Linear e> 	rtrapolation
Name Vrn1			✓ ▲ (new)

Figure 8: Select profile

In the profile origin fields enter (0,15) to mark the starting point of the profile. Click on the radio button **Linear extrapolation** in the **Before start of profile** section and confirm that **Linear extrapolation** is set in the **After end of profile** section (figure 9).

Profile Variation			×
Analysis category	2D Inplane		
Vertical axis	∨ Ne	gative 🗸]
Available	Included		
hydrostatic pressure	Profile	nigin x	y origin
	1 hydrostatic pr	0.0	15
	<<		
New Edit			
Evaluation outside ra	nge		
Before start of pro	file	After end of	profile
O Error		OError	d and only a
 Linear extrap 	olation	 Exten 	extrapolation
Name Vrn:			✓ (new)
< <u>B</u> ac	k <u>N</u> ext > Eini	sh <u>C</u> anc	el <u>A</u> pply <u>H</u> elp

Figure 9: Enter profile details

Repeat for each of the points (18,15), (30,23), (48,29) and (66,32). Finally, enter 'water table' in the **Name** field and click on **Finish** (figure 10).

Profile Variation					×
Analysis category	2D Inpla	ane			
Vertical axis		~	Negative	\sim	
Available		Included			
hydrostatic pressure) [Profile	x origin	y or	rigin
		1 hydrostatic	pr 0.0	1	5
	[2 hydrostatic	pr 18	1	5
		3 hydrostatic	pr 30	2	3
	>>	4 hydrostatic	pr 48	2	9
		5 hydrostatic	pr 66	3	2
	11				
New Edit. Evaluation outside rai					
Before start of pro	file		After end	of profile	
OError			OErr	or	
O Extend start v	/alue		ŎEX	tend end value	
Linear extraps	olation		۰	ear extrapolation	
Name	er table)		~	▲ (new)
< <u>B</u> ad	k №	ext >	<u>Einish</u>	ancel Apply	Help

Figure 10: Finish water pressure distribution definition

Enter 'water table' in the Name field and click on Finish (figure 11).

Water Pressure Distribution	
Analysis category 2D Inplane	
Pressure profile	
O Calculated from phreatic surface	1:ground water $$
Density of fluid	1.0
Assigned to faces	
Include face pressure (for	water/solid interface)
O Assigned to continuum	
Fully defined by profiles, assigned	to continuum
Profile variation	2:water table
Name water table	▲ (new)
< <u>B</u> ad	د Next > Einish Cancel Apply Help

Figure 11: Name water pressure distribution

The water table load appears in treeview (figure 12). It is assigned to all the model surfaces.



Figure 12: Water pressure load in treeview

The phi-c convergence tolerance is increased from 0.01 to 0.001 to compare with the other solutions which are quoted to three decimal places.

Comparison



The porewater pressure distribution is shown in figure 13.

Figure 13: Pore water pressure distribution

Figure 14 shows contour plots of effective strain. At the start of the phi-c analysis the slope is already showing signs of failure. 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. At SF=1.145 the upper failure surface starts to form which is fully complete at SF=1.148.



Figure 14: Plots of effective strain at different safety factors

The factor of safety is compared to other results [1] in table 3 with LUSAS giving a slightly higher result than the other 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 MMC	1.148	

References

[1] RS2