

# **Slope Tutorial Manual**



# **Oasys Slope**

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This document has been created to provide a guide for the use of the software. It does not provide engineering advice, nor is it a substitute for the use of standard references. The user is deemed to be conversant with standard engineering terms and codes of practice. It is the users responsibility to validate the program for the proposed design use and to select suitable input data.

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## 1. Introduction

Slope is a program which is used for analysing the stability of slopes. The program is also applicable to earth pressure and bearing capacity problems, as well as to rock slopes and waste heaps.

The program offers a variety of established methods for calculating interslice forces. Choose from Fellenius or Swedish slip circle analysis, the Bishop horizontal method or the constant inclined method. For non-circular slip surfaces, the software offers you the equivalent Janbu methods. Slope also includes a variably inclined interslice force method which ensures that each slice is in equilibrium, both vertically and horizontally. Slope allows the user to apply partial factors, including Eurocode 7, to run Ultimate Limit State (ULS) analysis.

The software analyses reinforcing elements such as soil nails, rock bolts, ground anchors and geotextiles to BS8007/BS8081. The user can specify water pressure, material shear strength, surface loads and horizontal ground acceleration. Slope checks a range of slip circles and gives the user the option to force slips through a point or keep them tangential to a strata.

The calculation itself is based on verified and robust numerical methods. The simplicity of calculation enables new users to set up and run a slope stability problem within hours of training.

The tutorial examples deal with a simple slope stability analyses, but this Tutorial Manual is intended to familiarise the user with Slope. The examples should therefore not be used as a basis for practical projects.

Users are expected to have an understanding of soil mechanics and geotechnical theory, and should be able to work in a Windows environment. The tutorial lessons are also available in the examples folder and can be used to check you results.

It is important to realise that Slope is an advanced program analysing a complex problem and the user must be fully aware of the various methods of analysis, requirements and limitations discussed in the User Manual before use. The Tutorial Manual will not provide theoretical background information on the analysis method, nor does it explain the details of various methods of analysis available in the program. These details can be found in the User Manual for Slope. This also contains detailed information on the available program features. Short courses are also regularly organised and should you be interested in more hands-on experience you can contact <u>oasys@arup.com</u> for dates and program content.

# 2. Slope analysis methods

Slope offers the following analysis methods:

- Swedish Circle (Fellenius)
- Bishop's methods
- Janbu's methods (for non-circular slip surfaces)

All these methods of analysis use the method of slices to determine the factors of safety for slope stability. The detailed derivation for each solution is given in the User Manual.

The use of these methods allows analysis of both circular and non-circular slip surfaces to be carried out. The location of circular surfaces is defined using a rectangular grid of centres and then a number of different radii, a common point through which all circles must pass or a tangential surface which the circle almost touches. Non-circular slip surfaces are defined individually as a series of x and y coordinates.

The **ground section** is built up by specifying each layer of material, from the surface downwards, as a series of x and y coordinates. Slope allows the user to import dxf drawings to specify layers.

The **strength of the materials** is represented by specifying cohesion and an angle of shearing resistance. Linear variations of cohesion with depth can also be entered.

The **ground water profile** and pore water pressure distribution can be set individually for each soil stratum, using either:

- A phreatic surface with hydrostatic pore pressure distribution.
- A phreatic surface with a user-defined "piezometric" pore pressure distribution.
- An overall value of the pore pressure coefficient Ru.

A maximum soil suction can also be specified for each stratum.

Any combination of **reinforcement**, consisting of horizontal geotextiles or horizontal or inclined soil nails, rock bolts or ground anchors, can be specified. The restoring moment contributed by the reinforcement is calculated according to BS8006:1995.

Slopes which are submerged or partially submerged can be analysed.

**External forces** can be applied to the ground surface to represent building loads or strut forces in excavations.

Horizontal acceleration of the slip mass can be included to represent earthquake loading .

The calculated factor of safety can be applied to soil strength or the magnitude of the applied loads, by either

- a) causing failure to represent bearing capacity problems, or
- b) preventing failure for anchor forces.

Over-Design Factor can be calculated for an ultimate limit state factor set using Partial Factor Analysis.

# 3. Slope User Interface

The principal components of the user interface are illustrated below and these will be referred to in the tutorial manual.

Standard To	oolbar	Output Toolbar							- 0 - X-
File Edit View Data Analysis □ → □ × □ × □ ■ ▲ Φ □ → □ × ∞ ≪ A = ■ □ ★ ↓ □ × ×									
Input     Uvits	25.00 20.00 15.00 5.000	Graphical Input		25.00 20.00 18.00 10.00 5.000 .0 -8.000 -3				phical utput	Image: Constraint of the second sec
- Graphical Input - Output - Tabular Output	sLOPEmenski : Output			E SLOPEm	an.sld : Materials		-		
Gateway	Parameters	a aspects of \$109% including loads, piezomet	ie j	Material Detaults	A Descriptio	n Above GWL	C EN/m² Below GWL 0.00	D Condition Drained - Inser strengt	h 0.0
	ion of slip: DOMENTI Rindman site weight (MY/M) Type of analysis (MY/M) Type of analysis (MY/M) Type of analysis (MY/M) Analysis Options Tector of safety on : SNIAA Minimum number of alignet 1 Minimum number of alignet 1 Minim	Tabular Outpu	it P	10400	Made Ground Sendt Clay Sand Lenn	Table V	21.00	Unchained d - linear strengt	h 29.0

# 4. Simple Slope Analysis

To cover the features available, the stability of a slope with varied stratigraphy and water table and will be covered in this tutorial. This serves as a quick introduction to the Slope program.

Objectives

- Start a new project
- Create soil stratigraphy and input material properties using the Model Wizard feature
- Use the Graphical Input interface
- Apply water data and surcharges
- View calculation results
- Export tabular outputs
- Print and adapt graphical outputs

# 4.1 Geometry and Input Values

For a design problem, the site investigation data and testing should be used to determine the stratigraphy data and the material properties.

For this slope stability analysis, the following geometry will need to be plotted.



#### **Material Properties**

Description	Unit Weig	ht (kN/m2)	Condition	Phi (deg)	Cohesion c' (kN/m2)
	Above GWL	Below GWL			
Embankment	15	19.5	Drained - linear	20	5
Soil			strength		
Foundation Soil	18	21.5	Drained - linear	25	10
			strength		
Bedrock	22	24	Drained - linear	40	15
			strength		

#### Strata Co-ordinates

Embankment

x	у
0	14
15	14
35	4
50	4

<u>Foundation</u>	
х	у
0	4
35	4
50	4

<u>Bedrock</u>	
x	у
0	0
50	0

# p6 Section

#### **Groundwater Profiles**

<u>Original</u>		
х	у	
0	11	
15	10	
35	3	
50	3	

<u>Raised</u>	
х	у
0	14
15	14
35	4
50	4

# 4.2 Creating the Input

- 1. Open the Oasys Slope Program.
- 2. In the Welcome Screen, select Create a new file

Welcome t	o Slope		×
۲¢	Slopc 19.0 SP3 build 19	5	About Home Page
	<ul> <li>Create a new file</li> <li>Open an existing file</li> </ul>	2	
	Select recent file:	SectionBB_DA1-2_rev1.sld SectionBB_DA1-2_rev1.sld MBRM_T_A1_Static.sld Slope1 sld FS-0 821.sld	
	Show this welcome s	creen on startup	OK Cancel

3. The Input Wizard will open. In the Titles and Units box, fill in the information about the analysis.

Click on <i>Next</i> .				
New Model Wizard : Title:	s and Units			×
Job Number	Initials ZF	Edit Date		
Job Title				
Slope Tutorial				
Subtitle				
Simple Slope Analysis				
Calc. Heading				
Notes				
			*	
	Units			
			< Back Next >	Cancel

(Hint: Choosing Units allows you to change the units from the standard SI option)

4. In the **Material** section of the Wizard, enter the Embankment material values given in Section 4.1.

5. In the **Stratum Definition** section of the Wizard, enter the co-ordinates for the Embankments given in Section 4.1.

Select a Hydrostatic pore pressure distribution with the Unit weight of groundwater equal to 10 kN/m<sup>3</sup>.

Name	Emabankment			A Coordinates (	B top of strata)	Â
Material	Embankment	-	Point	(n		
Material	Emplement			x	у	
Pore pressure distributio	n		Defaults			
			1	0.00	14.00	
Hydrostatic	None		2	15.00	14.00	
0.1	0.000		3	35.00	4.00	E
			3 4 5	50.00	4.00	
Unit weight of groundwate	10	[kN/m <sup>3</sup> ]	5			
one weight of groundwate	64 10	ferom 1				
						-
						Ŧ

6. In the **Groundwater Co-ordinates** section of the Wizard, enter the co-ordinates of the Original groundwater profile given in Section 4.1.

(Note: Should the user wish to compare the impact of different groundwater profiles, they can add water profiles in the Ground Water section of the Gateway, once they have exited the wizard, and apply this in the Strata section).

7. In the **Slip Surface Definition** section of the Wizard, choose a Grid with centre (25, 15) with an angle of rotation at -20 degrees. This information is entered into the *Circle Centre Specification* section.

In the *Centres on Grid* section, the Grid should have 15 points at 1m distance. These points represent centres at which slip circles would be calculated.

(Hint: Choosing a finer grid gives more accurate Over Design Factors. However, the Slope analysis will take longer to carry out as more calculation points have been chosen. The user would be advised to refine the grid around the worst case slip circle centre after the initial analysis has been carried out.)

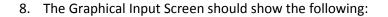
For the Circle Radius Specification, choose the Defined radii method with an initial radius of 1m and an increment of 1m.

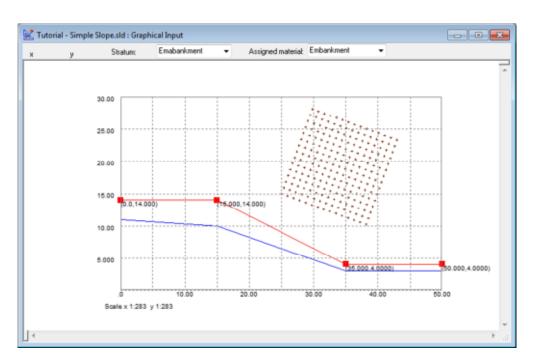
(Note: For a discussion of the different methods, please refer to the User Manual, Section 4.3.10.)

Check Extend Grid to find minimum factor of safety. This will enlarge the grid if the minimum factor of safety is outside the specified grid.

Model Wizard	: Slip Surfa	ce Definition				
Circle centre s Single Coordinates:		Grid t if a grid specifie	Com	adius specification mon point ped radii	Tangent s	urface
	25 15	0	Coordin	ates:x [m] 0 t to stratum: 1	y [m]	0
(about bottom				dius [m] 1 it radius	Increment [m] Limiting radius [m]	1
Centres on gri Definition of c		local axis		Features of grid		
x direction:		y direction:		Extend grid to	find minimum factor	of safety
number	15	number	15			
spacing [m]	1	spacing [m]	1			
				< Bac	k Finish	Cance

Now select Finish.





If the Strata, Groundwater or Grid are showing incorrectly, the user can amend these through the Gateway with the correct values.

9. Double click on General Parameters in the Gateway.

The default options of a static analysis of a circular slip surface should be selected.

Slip surface type © Circular © Non-circular	Direction of slip     O Downhill ○ Increasing x ○ D	ecreasing x
Project slip Along Slip 👻	Minimum weight [kN]:	0
Type of analysis	Horizontal acceleration (%g)	0
Static Pseudo-static C	yclic Apply	Undo

(Note: Should the user wish to carry out Pseudo-static analysis or analyse a Non-circular slip surface, guidance is given in the Slope User Manual)

10. Double click on **Analysis options** in the Gateway.

The default options of a Bishops analysis using variably inclined interslice forces should be selected.

Analysis method	Interslice forces	Analysis option		
Swedish	Swedish Orizontal		strength	
Bishop     O     Parallel inclined		FOS on Disturbing surface loads		
<ul> <li>Janbu</li> <li>Variably inclined</li> </ul>		FOS on Restoring surface loads		
-		Partial Factor	Analysis	
Soil nail analysis Method for Soil Na (BS8006-2:2011):	il restoring moment	Maximum iterations	300	
Option 1		Minimum slices	25	
Option 2		Reinforcement active		
Option 3		Distribute surfac	e loads	
Method for analys strength:	ing nail bond			
Radial stress e	equal to vertical stress	Apply	Undo	
Radial stress b	ased on HA 68/94	- where	0100	

(Note: . The user can familiarise themselves with the different methods by reading Section 3 of the User Manual)

- Double click on Materials in the Gateway Inputs.
   Enter the material properties for Foundation Soil and Bedrock (given in section 4.1).
- 12. Double click on Embankment in the **Strata** section of the Gateway Inputs.

Click on the *Add stratum* tab at the top of the window. Enter the Foundation strata co-ordinates given in Section 4.1. Click on Apply when complete.

Name	Foundation S	oil		Stratum Co	ordinates		
					A	В	
Material	Foundation S	oil	•	Point	Coordinates (to [m]	p of strata)	
Pore pressu	re distribution				x	y	
O Hydrosta	atic	Piezometric		Defaults 1	0.00	4.00	
				2	35.00	4.00	
Specifie	d Ru	None		3 4	50.00	4.00	
Max suction (h	nead of water)	0	[m]				н
Unit weight of	groundwater	10	[kN/m²]				
Ru value:		0.2	]				
G₩ surface:	GW Profile 1		•				
Piezometers:			Ŧ				

Now repeat to enter the Bedrock strata details.

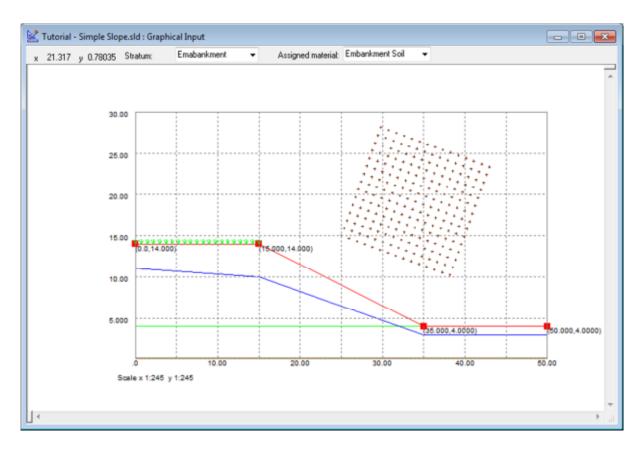
13. Double click on **Surface Loads** in the Gateway.

Enter a vertical live load of 10 kN/m per horizontal m. This load should act between (0,14) and (15,14) along the crest of the slope.

(Note: A default of No is selected for the Use in-pull column. This excludes the surcharge in the In-pull calculation for reinforcement. Section 3.6 of the User Manual gives more details about this calculation.)

	A	B	C	D	E	F	G
oad -	Limits of Lo	aded Area	Distributed Loa	d [kN/m hor/m]	Permanent	Favourable	Use in
	Left [m]	Right [m]	Vertical	Horizontal	load/	load/	pull-
efaults	0.00	0.00	0.00	0.00	Permanent	Unfavourable	No
	0.00	15.00	10.00	0.00	Variable 🔔		No
_							

14. Check the **Graphical Input**. This should show the added strata and the surcharge.



- Save the file prior to analysis by selecting File > Save.
   Save the file as Simple Slope.sld
- Σ Click on the analyse button to carry out the Slope Stability Analysis.

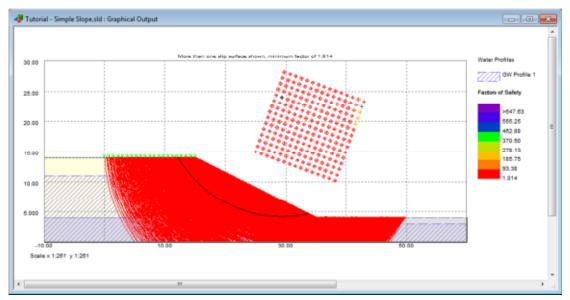
# 4.3 Viewing the Results

# 4.3.1 Graphical Output

#### Viewing a number of Slip Circles

1. On completion of the analysis, the Graphical Output window will show.

This shows the minimum factor of safety and the worst case slip circle.



It also shows the range of slip circles around the worst case slip circle.

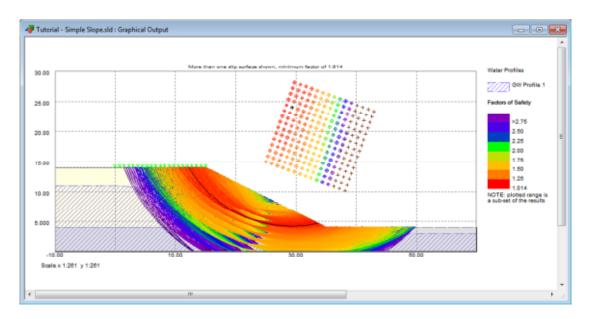
A large range of Factors are shown.

To view a more realistic range, select Graphics > Graphical Output > Display Settings

#### Select a Maximum FOS of 3.

Edit graphics settings	
FoS range to show on d	isplay
Minimum:	1
Maximum:	3
Contour interval on grid of centres:	1
Maximum number of slip circles to display:	5000
OK Ca	ncel Reset

#### A more realistic range will now show:

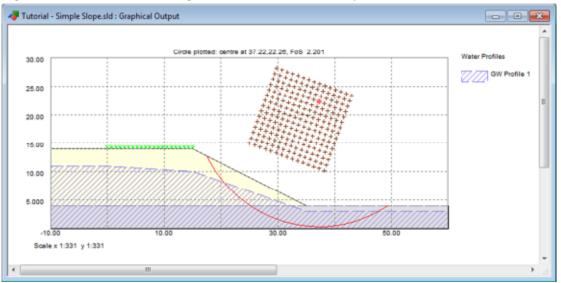


#### Viewing a Single Slip Circle

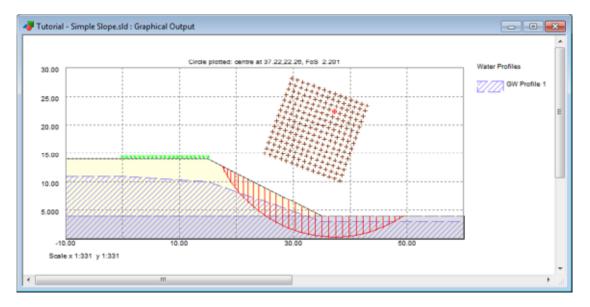
3

To view the worst case slip circle, switch off the *Plot all circles* icon.

1. Right click on the circles in the grid to view Factors of Safety for different circles.



Click on the Slices icon to view the slices analysed for the specific Slip Circle.



1<mark>0</mark>1

To view the slice diagram for a particular slice within the interslice analysis, click on the *Slice Diagram* icon. Then click on a slice of interest in the Graphical Output screen.

🛷 Tutorial - Simple Sl	ope.sld : Sice diagram
14.00	Circle no. 3703 Centre (37 219455718804 22 258439110352) Radius 22m Equilibrium forces on alice 13 for FoS 2 2007075170898 Force Polygon: scale 1M to 0.03m on grid
12.00	
10.00	
8.000 -	72.211112978074
6.000 <sup></sup>	285.15194702148
4.000 -	
2.000 -	08.842496779297 37.1088556912912
.0 -	
	09 25'00 35'00 45'00 55'00
Scele	11148 y 11149
*	m

#### **Annotating and Printing Graphical Outputs**

1. Close the Graphical Output box to delete all the changes to the users selection of slip circle. Reopen to show the worst case slip circle.

a<sub>+</sub> Click on the *New Label* icon.

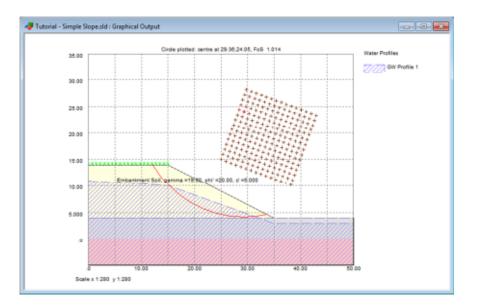
In the Text Label Box choose to label the Soil label and check the soil name and properties boxes.

Click the OK button.

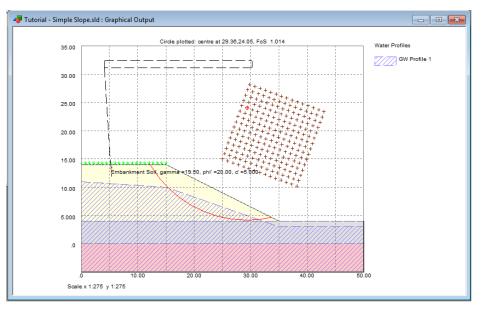
ext Label	
Label type C General text  O Soil label  O Slip surface label	el OK Cancel
Text for general label (use RETURN for line breaks)	
Current settings         Soil name         Drainage condition         Image conditition         Image condititi	Field separator Comma New line

Now click on the embankment strata.

aĮ



# Click on the *Edit Label* icon. Position the cursor near the red spot shown on the top left of the label.



Click and drag the label to a more suitable position.

2. Select File > Print Preview to view the final output.

The user will note their inputs in the Titles section of the Gateway show in the printout.

Should the user wish to change any information regarding the analysis, they can do so by changing the inputs in the **Title** section of the Gateway.

(Hint: The user can change the company information by selecting **Tools > Preferences**)

### 4.3.1 Tabular Output

- 1. Double click on Tabular Output in the Gateway
- 2. Select to view the Summary Results and Detailed Results (Worst Case)

Page Setup	
Select items to print.	
Notes	Reinforcement
General parameters	C Groundwater
Analysis method	Slip surfaces
Method partial factors	Surface loads
Materials	Summary Results
🕅 Soil Strata	Vetailed Results (worst case)
OK Cancel	Select All

3. View the results for each slip centre:

🔄 Tutorial - Simpl	e Slope.sld : Outpu	t			• 💌
RESULTS OF AN	I YSIS				^
In the follow:	ing tables, va	lues in italics ar	e factored val	10.5	
		d Method Partial H			
Slip Centre	Radius Slip	Comment/ Distur		Reinforcement	
	Weight	FoS Moment	Strength	Restoring	
			Restoring	Moment	
			Moment		
x [m] y [m]	[n] [kN/n			[kNm/m]	
25.000 15.000		Radius too smal	-		
25.000 15.000		Radius too smal	-		
25.000 15.000		Radius too smal Radius too smal	-		
25.000 15.000 25.000 15.000		Radius too smal Radius too smal	-		
25.000 15.000			1 .278 <i>235.72</i>	0.0	
25.000 15.000			5.36 707.50		
25.000 15.000			3.76 1465.4		
25.000 15.000			3.76 1468.4 59.1 2467.1		
	10.000 903.		05.4 3728.2		
25.000 15.000			53.5 5313.5		
	12.000 1253		83.2 8901.6		
25.000 15.000			91.3 12448.		
	14.000 2867		797. 16556.		
25.000 15.000			508. 21336.		
25.000 15.000			477. 36854.		
25.000 15.000			648. 50050.		
25.000 15.000			014. 64578.		
25.000 15.000			581. 81036.		
25.000 15.000			349. 99537.		
25.000 15.000			317. 120270.		
25.000 15.000			483. 143360.		
25.000 15.000			850. 169000.		
25.000 15.000			424. 197290.		
25.000 15.000			197. 228420.		
20.000 15.000	1400		220420.	0.0	+

(Hint: Review Section 5.2.1 of the User Manual to view the definition of the Column Headings and the definition of any error messages, such as the "Radius too small" shown.)

4. Scroll down to view the detailed results for the worst case slip:

Tutorial - Simple Slope.sld : O	utput			- • •	
WORST CASE Centre at (29.360m,24.05 Iterations: 45 Net vertical force [kN/m Net horiz force [kN/m]:	Ho 1]: 1.2996 S1 3.0358 Di Re Re	dius 20.000m riz acceleration ip weight [kK/m] sturbing moment [ storing moment [ inf.Rest.Moment [ ctor of Safety: 1	1268.5 [kN/m]: 9686 [Nm/m]: 9823 [kNm/m]: 0.0	. 6	
The system of interslice when the strengths avail factor of safety. The i are in equilibrium with	able at the bas nterslice force	es are divided by s shown in the fo	the comput llowing tab	le	
Slip surface coordinates					
Point x [m] y [m]	L R	T E	E	(u)	
1 12.071 14.000	[kN/m <sup>2</sup> ] [kN/m <sup>2</sup> 38.04		0.0	0.0	
	-31.408 -31.40		0.42564	0.0	
	-24.963 -24.96		2.7534		
	-18.724 -18.72		7.0906		
	-12.700 -12.70		13,461		
	-6,9023 -6,902		21.802		
7 15,000 10,134	-1.3393 -1.339	3 24.717	31,957	0.0	
0 15.201 9.9297		0 26.665	35.240	0.0	
9 15.850 9.3072	3.9516 3.951	6 32.531	47.023 0	.78077	
10 16.527 8.7145	7.5091 7.509	1 37.738	60.731	2.8193	
11 17.230 8.1528	10.665 10.66	5 42.044	75.566	5.6873	
12 17.958 7.6234	13.413 13.41	3 45.264	90.729	8.9960	
13 18.708 7.1272	15.748 15.74	8 47.276	105.45	12.401	
14 19.481 6.6653	17.665 17.66	5 48.028	118.99	15.603	
15 20.273 6.2385	19.160 19.16	0 47.541	130.72		
16 21.083 5.8478	20.230 20.23	0 45.903	140.05	20.463	-
17 21.911 5.4940	20.873 20.87	3 43.266	146.53	21.784 *	
•					

5. Select **File>Export**. Save the file with a .csv extension to open the results in Excel. This will allow the Engineer to further analyse the results.

# 4.4 Test Yourself

Using the process outlined in the previous sections, apply the Raised Groundwater Profile outlined in Section 4.1.

Compare the impact of the new groundwater profile on the factor of safety.

Print out your new results.

(Hint: Remember to change the Titles section to give appropriate headings and save this file under a different name)

# 5. Partial Factor Analysis and Reinforcement Design

Following setting up a Slope Stability analysis, the user may wish to carry out an Ultimate Limit State (ULS) analysis. To follow the design process, this tutorial will show the user how to apply EC7 partial factors to the analysis set up in Section 4 The user will then be guided through reinforcement design to obtain an appropriate slope design.

Objectives

- Apply partial factors
- Apply reinforcements

# **5.1 Partial Factor Analysis**

- 1. Open the file created in the previous section with the Original Groundwater Profile (Simple Slope.sld)
- 2. Save as EC7 Analysis.sld
- 3. Amend the Titles section to show that this file is carrying out a factored analysis
- 4. Double click on **Analysis method** in the Gateway.

Select Partial Factor Analysis in the Analysis option section. Click on Apply

Analysis method	Interslice forces	Analysis option			
Swedish	Horizontal	FOS on Shear strength			
Bishop	Parallel inclined	FOS on Disturbing surface loads			
Janbu	<ul> <li>Variably inclined</li> </ul>	FOS on Resto	ring surface loads		
O'daba		Partial Factor Analysis			
Soil nail analysis Method for Soil Nail restoring moment (BS8006-2:2011): Option 1 Option 2		Maximum iterations Minimum slices Ø Reinforcement a	300 25 ctive		
O Option 3		Distribute surface loads			
Method for analys strength:	ing nail bond				
Radial stress e	equal to vertical stress	Applu	Undo		
Radial stress t	ased on HA 68/94	Apply	Undo		

5. Double click on **Method Partial Factors** in the Gateway.

Select EC7 DA1-1 to select Eurocode 7 Partial Factors for Design Approach 1, Combination 1.

Click Apply.

Tutorial - EC7 Analysis.sld : Method Partial Factors								
Select standard	factors:			Soil factors				
EC7 DA1-1		•		Unit weight (γ)	1			
External surcharge				Drained cohesion $(\gamma_{c'})$	1			
	Favourable	Unfavourable		Undrained cohesion( $\gamma_c$ )	1			
Permanent	1	1.35		Friction angle( $\gamma_{\phi}$ )	1			
Variable	0	1.5						
Moment correction factor( $\gamma_x$ ) 1 Economic ramification of failure( $\gamma_n$ ) 1								
Reinforcement pull-out(γp) 1.5			Sliding along reinforcement( $\gamma_S$ )		1.5			
	C	Apply	Modif	y Add	]			

It can be seen that this primarily factors actions (i.e. surcharges and reinforcement).

(Hint: To better understand the Eurocode 7 design approach, the user can download information from the Oasys Eurocode 7 seminar (<u>https://www.oasys-software.com/index.php/webinars/webinar/ec7\_and\_geotechnical\_analysis/</u>) or review the Eurocode 7 design code.)

- 6. Prior to analysing, save the analysis file.
- **2** Click on the *Analyse* icon to carry out the Slope Stability Analysis.
  - View the overdesign factor.
     Print the output showing the worst case slip circle.

Σ

Click on the Delete Analysis icon.

- 8. Apply EC7 DA1-2 in the **Method Partial Factors** input.
- 9. Re-analyse and compare the overdesign factor for the worst case slip for Design Approach 1, Combinations 1 and 2.

The results for Combination 2 demonstrate the Slope is failing in the Ultimate Limit State.

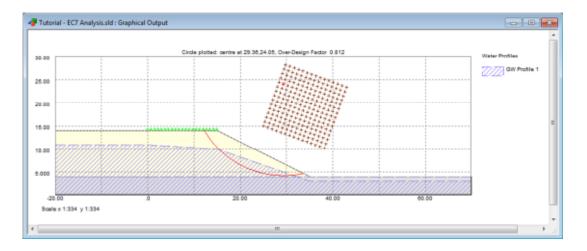
Save this analysis.

(Note: The user should find that Combination 2 gives a lower overdesign factor. This is as expected, as Combination 2 generally factors materials. However, if reinforcement is added or extra surcharges are applied, Combination 1 may become more critical as this generally factors actions.)

# **5.2 Reinforcement Design**

Based on the results in the Eurocode 7 analysis in Section 5.1, the user may wish to look into amending the slope or designing reinforcement. This section looks into designing reinforcement to increase the overdesign factor above 1.

- 1. Open the file created in the previous section (EC7 Analysis.sld)
- Double click on the Graphical Output in the Gateway.
   The Ultimate Limit State analysis shows an Over design factor below 1.



3. Double click on **Reinforcement** in the Gateway.

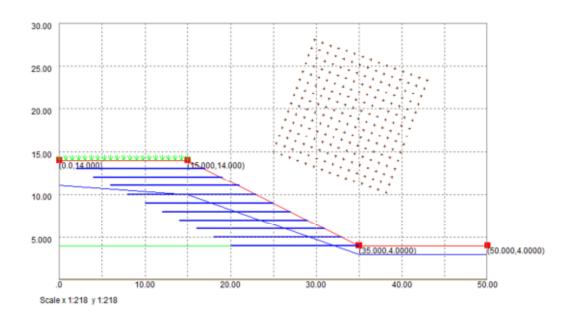
Input data for a Geotextiles from the crest to the base of the slope with an Ultimate Capacity of 100kN.

An example input is shown on the following page.

Analyse and print the output with the new Overdesign Factor.

Is the slope with new reinforcement design acceptable?

Reinforcement 1 Add reinforcement			
Name: Reinforcement 1	Type:	Geotextile	-
Layers		Bond Length b	
Single  Multiple Number:	12		
Uppermost Level (m): 14 Spacing (n	n): 1		
	-	Bond strength (kN/m):	
Offset from slope surface (m):	0	Specify 0	
Length L (m):	<ul> <li>Calculate from effective stress</li> </ul>		
Top layer: 15 Bottom layer:	15	Angle from horizontal w (*):	0
Anchor force is applied as surface load		Prestress (kN):	0
Capacity and Spacing		Effective width (%)	100
Out-of-plane spacing (m):			
Ultimate tensile 100	)	$\bigwedge$	•
Plate capacity (kN/m):			3
Material partial factors		/ /L	
SLS (all factors=1.0)	Select		_



4. In the Reinforcement Section of the Gateway, click on the Select button in the Materials Partial Factors section.

Select standard factors: PES geotextile 120years/gravel		Creep reduction	0.6
		Manufacture	1.2
Friction interaction		Extrapolation of test data	1.3
	0.6	Damage	1.4
Adhesion interaction	0.6	Environment	1.1
		Strength	1
ОК	Cancel	Add	odify

This section has a number of predefined partial factors for reinforcement.

Select PES geotextile 120year/gravel and click OK.

(Note: The user can click on **View>Partial Factors** to view the Partial Factor and Material Partial Factors available. These can be amended by the user and will be saved for future analyses.)

5. Reanalyse and view the impact on the final Overdesign Factor.

# 6. Importing DXF Drawings

For more complex slope profiles and stratigraphies, inputting the co-ordinates through the table interface can be time consuming. Oasys Slope allows the user to import dxf drawings and apply a strata and material or groundwater table to the different surfaces.

Objectives

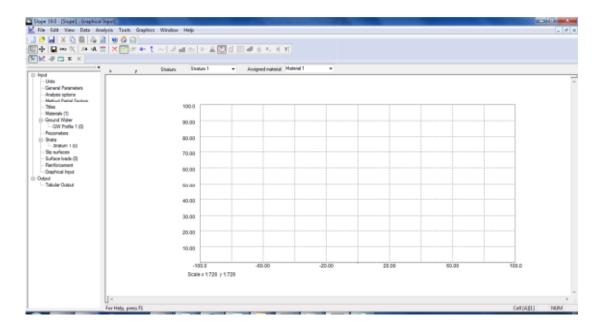
- Import dxf drawings
- Limiting minimum slip circle size

# 6.1 Importing DXF Drawing

- 1. Open a new Slope analysis file.
- 2. In the wizard, input information into the Titles and Materials section.
- 3. In the Materials section, input the properties of the Embankment Soil (properties in Section 4.1).
- 4. In the Stratum Definition, Ground Water Co-ordinates and Slip Circle definition sections of the Wizard, leave all inputs blank.

Click Finish.

5. The following screen will show on completing the wizard:

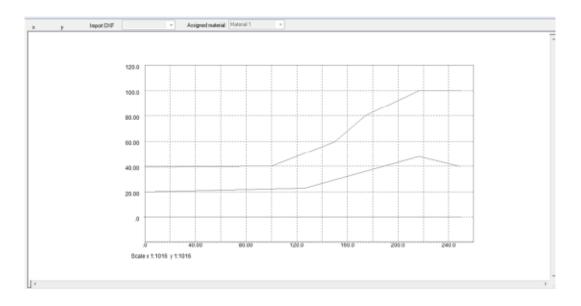


- 6. Click File > Import > DXF File
- 7. Import the file supplied with this tutorial (Slope Tutorial.dxf)

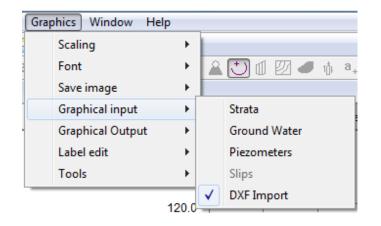
8. Place the origin co-ordinates at (0,0)

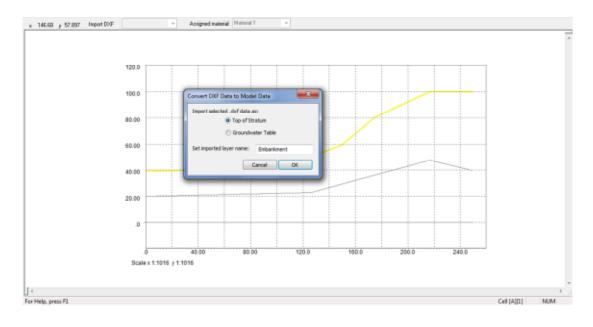


9. The dxf will show in the Graphical Input screen:



10. Click on **Graphics > Graphical input** and check *DXF Import* to allow the user to assign properties to different lines.





11. Click on the top line and assign this line the Foundation Strata.

- 12. Assign the next line down as a Groundwater Table titled Original WT
- 13. Assign the bottom line to the Bedrock Strata.
- 14. Double click on **Materials** in the Gateway and add the Bedrock Strata from Section 4.1.
- 15. Double click on **Strata** in the Gateway and assign each strata the appropriate material properties, and Hydrostatic pore pressure distribution with appropriate groundwater table (Original WT).
- 16. Double click on **Slip Surfaces** in the Gateway. Choose appropriate an appropriate grid location and spacing.

(Hint: The analyses may run slowly with too many grid points. Start with a coarse grid and refine around the worst case slip circle)

The user is required to find a slip circle that passes through the base of the slope (100,40). Choose the Common Point method of circle specification.

17. Run the analysis.

# 6.2 Limiting the Minimum Slip Circle Size

1. Double click on **General Parameters** to apply a Minimum slip circle weight. If a large enough weight is applied, the user can avoid picking smaller slip circles as their worst case slip surface. Choose 1000kN and compare the slip surface to the previous analysis.