rocscience

Slope Design with Eurocode 7

1. Introduction

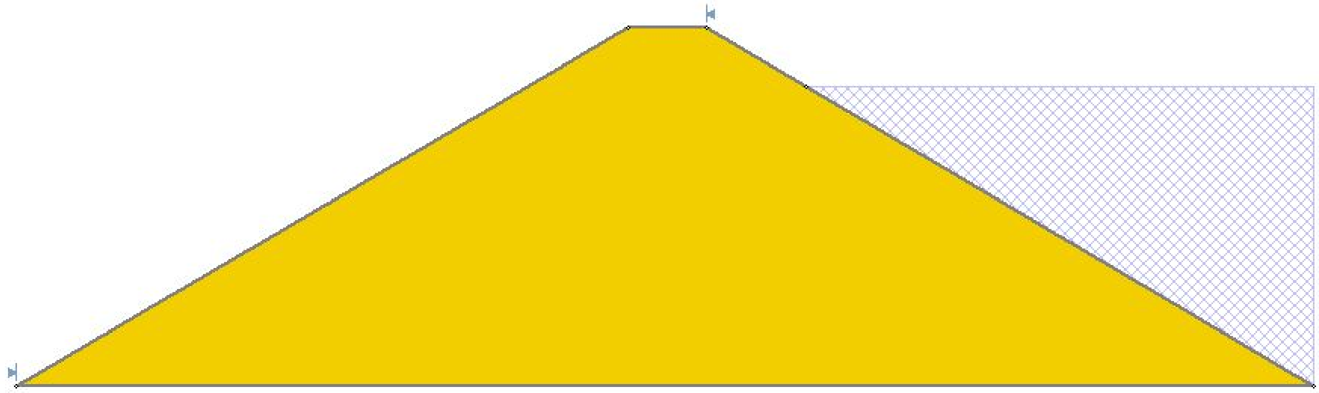
Eurocode 7 is a design document that establishes rules and standards for geotechnical engineering design across Europe (BSI, 2004). Eurocode 7 represents a major change in design philosophy. Traditionally a single, lumped factor of safety accounts for all of the uncertainties in the problem. With Eurocode 7, partial factors of safety are applied to different components of the analysis. The partial factors are applied prior to the analysis to give design values that are used in the calculation. The final result is an over-design factor, which must be greater than 1 to ensure the serviceability limit state requirement is satisfied. For more information on using Eurocode 7 in geotechnical design, see Smith (2006) and Bond and Harris (2008).

This tutorial describes how to design a slope to Eurocode 7 specifications using Slide2

2. Model

The model is based on example 5.12 in Smith (2006). It is a simple earth dam on an impermeable base for which the downstream side is to be analyzed. First, the problem will be analyzed in the traditional way and a factor of safety will be obtained. Then the Eurocode design analysis will be performed.

Start the Slide2 Model program. All tutorial files installed with Slide2 can be accessed by selecting **File > Recent Folders > Tutorials Folder** from the Slide2 main menu. To start with open the file *Tutorial 21 Eurocode initial.slmd* data file.



Some features of this model to note:

- The dam is assumed to sit upon a high-strength material that is not included in the model.

- The Groundwater Method = Steady State FEA (finite element analysis)

• Since we are analyzing the downstream slope, the failure direction is Right to Left, and we are using the Auto Refine Search method for circular surfaces.

3. Compute

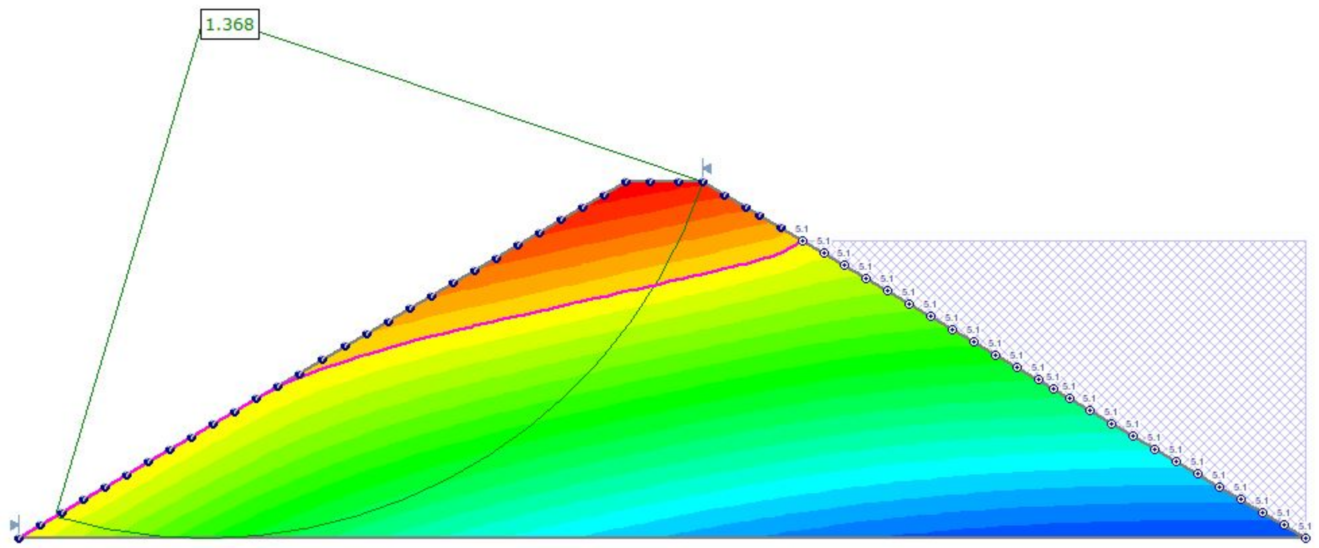
Choose Compute from the Analysis menu to perform the analysis. Make sure the Initial scenario checkbox is selected and select OK.

Since this model uses finite element seepage analysis, you will first notice the groundwater seepage analysis is computed, followed by the slope stability analysis.

Choose Interpret from the Analysis menu to view the results.

4. Interpret

The Interpret program shows the results of the Bishop Simplified analysis by default. The factor of safety is 1.37 indicating a stable slope.



5. Multi Scenario Modeling

Return to the Slide2 Model program.

• Right-click on the **Initial scenario** in the **Document Viewer**, and select **Duplicate Scenario** from the popup menu.

• Right-click on the newly created **Scenario 2** and select **Rename** from the popup menu. Change the name to **Design Approach 1 Combination 1**

6. Eurocode 7 - Design Approach 1 - Combination 1

Make sure that the Design Approach 1 Combination 1 scenario is selected.

Open the Project Settings dialog from the Analysis menu. On the left side click on Design Standard. Eurocode 7 offers three different design approaches for checking GEO limit state requirements (failure or excessive deformation of the ground). Each approach gives a set of partial factors to be used in the analysis. Design Approach 1 is the most common in the UK so this will be examined in this tutorial, however, all three design approaches are included in Slide2

Design Approach 1 actually specifies two different combinations of partial factors. The first factors are the action forces, and the second factors are the resisting forces through the material properties. We will test both combinations in this tutorial. Under design standard, select Eurocode 7 – Design Approach 1, Combination 1.

Click on the View Partial Factors button. You will see the following dialog:

Partial Factors

Permanent Actions (A)		
Unfavourable	γ_G	1.35
Favourable	γ_G	1
Variable Actions (A)		
Unfavourable	γ_Q	1.5
Favourable	γ_Q	0
Material Parameters (M)		
Effective cohesion	$\gamma_{c'}$	1
Coefficient of shearing resistance	$\gamma_{\varnothing}$	1
Undrained strength	γ_{Cu}	1
Weight density	γ_{γ}	1
Shear strength (other models)		1
Resistance (R)		
Earth resistance	γ_{Re}	1
Anchorage (R)		
Tensile and Plate strength	γ_a	1.1
Shear strength	γ_a	1.1
Compressive strength	γ_a	1.1
Bond strength	γ_a	1.1
Seismic		
Seismic Coefficient		1

OK Cancel

Here you can see that the factor for the Permanent actions (unfavourable) is 1.35. This essentially means that the driving force in the analysis will be multiplied by 1.35. The factors for the material properties are 1, so they will be unchanged in the analysis.

Click **OK** to close the Partial Factors dialog and click OK to close the Project Setting dialog.

Select **Save** to save the new scenario

7. Compute

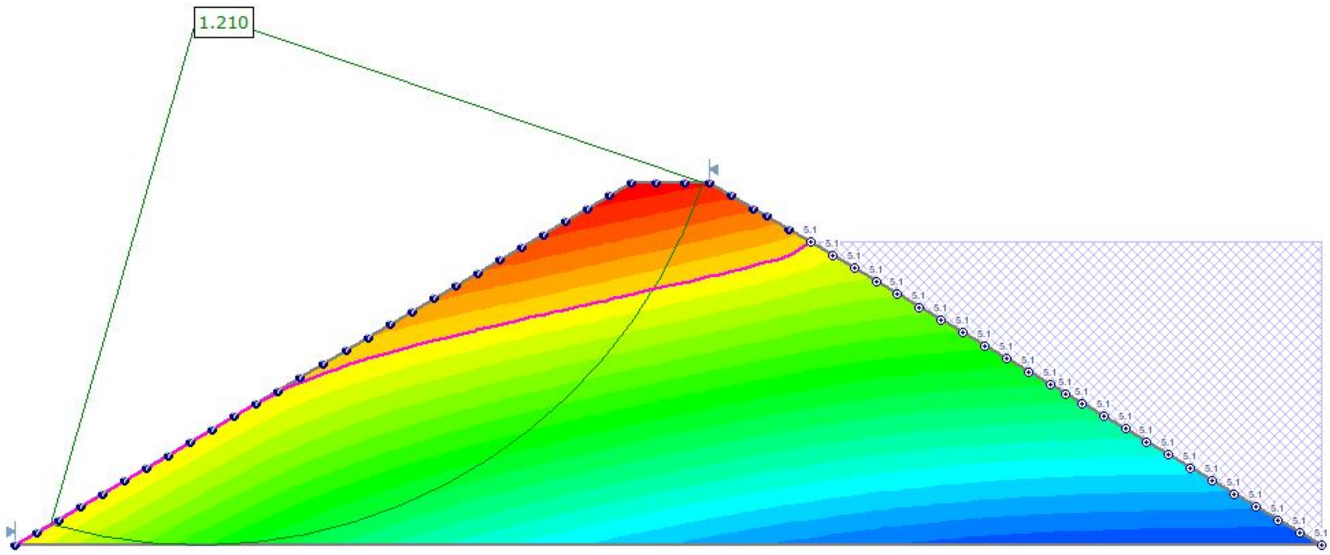
Choose **Compute** from the Analysis menu to perform the analysis. In the **Scenario Compute** dialog, notice that only the **Design Approach 1 Combination 1** scenario is selected since the Initial scenario has already been computed.

Select **OK** to compute. When the analysis is finished choose Interpret from the Analysis menu to view the results

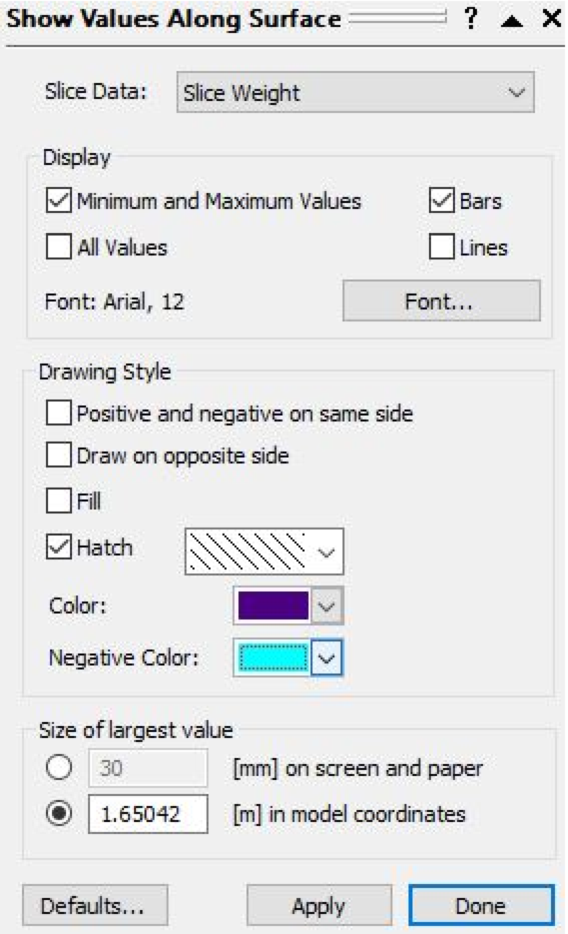
8. Interpret

The Interpret program shows the results of the **Bishop Simplified** analysis by default. The Slide2 *Tutorial Manual Tutorial 21: Slope Design with Eurocode 7* 21 - 5 plot is showing the over-design factor (Γ), not the usual factor of safety (F). The over-design factor is the ratio of resisting force to driving force for the given partial factors. If Γ > 1, then the limit state requirement is satisfied for this Design Approach.

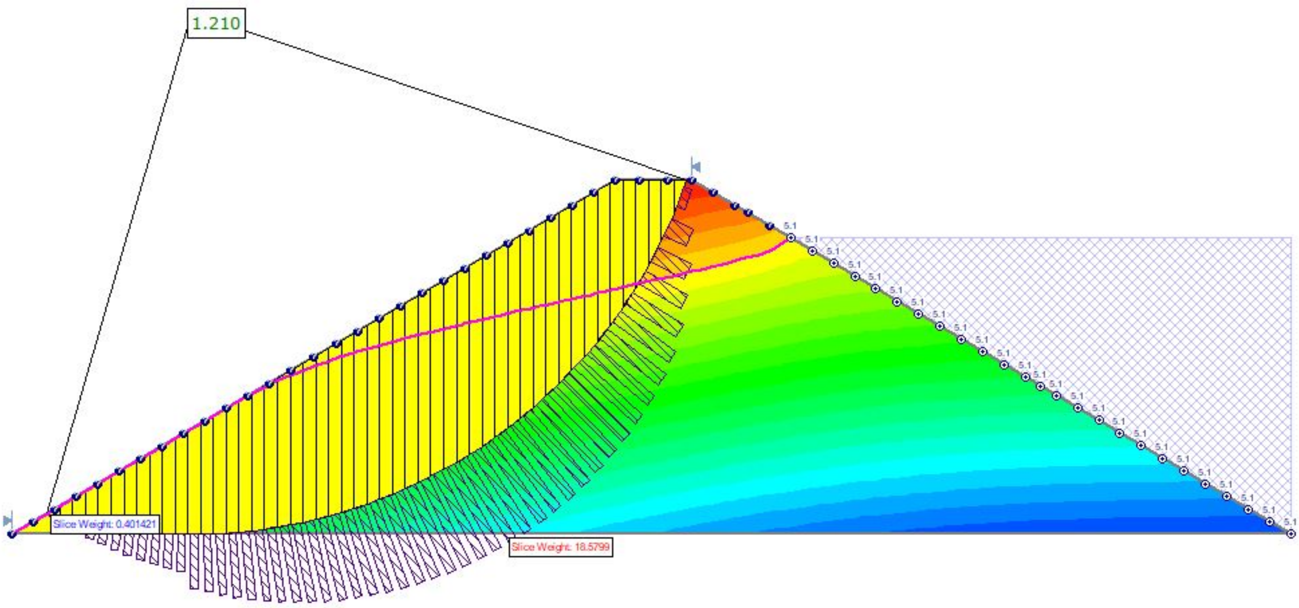
So, you can see that for Design Approach 1, Combination 1, Γ = 1.210, which is greater than 1, therefore this slope is considered serviceable.



We can now examine this in a bit more detail. View the slices by selecting **Query > Show Slices**. Now we can plot the weight of each slice by going to **Query > Show Values Along Surface**. For Slice Data, choose **Slice Weight** as shown:



Click Done and you will see the weight of each slice as shown:



Now, it is interesting to compare this plot to the same plot for the Initial scenario (without the Eurocode Design).

If it is not already open in the Interpret program, open the results from the initial analysis performed earlier in the tutorial. Repeat the above steps to display the slice weights.

You can see that the maximum slice weight in the Eurocode analysis is about 1.35 times the maximum slice weight in the initial analysis. This reflects the partial factor of 1.35 applied to the driving action for Design Approach 1, Combination 1. (Note: the slice weights are not exactly 1.35 times because the surfaces and slices are not exactly the same).

9. Eurocode 7 - Design Approach 1 - Combination 2

Go back to the Slide2 Model program.

Create a third scenario.

- Right-click on the Initial scenario in the Document Viewer, and select Duplicate Scenario from the popup menu.

- Right-click on the newly created Scenario 3 and select Rename from the popup menu. Change the name to Design Approach 1 Combination 2.

Open the Project Settings dialog from the Analysis menu. On the left side click on Design Standard. Change the Design Standard to Eurocode 7 – Design Approach 1, Combination 2.

Click the View Partial Factors button. Here you can see that the partial factors for the actions are now 1, but for the material parameters, the factors are greater than 1, indicating that reduced material strength will be used in the analysis.

Partial Factors

Permanent Actions (A)		
Unfavourable	γ_G	1
Favourable	γ_G	1
Variable Actions (A)		
Unfavourable	γ_Q	1.3
Favourable	γ_Q	0
Material Parameters (M)		
Effective cohesion	$\gamma_{c'}$	1.25
Coefficient of shearing resistance	γ_{ϕ}	1.25
Undrained strength	γ_{Cu}	1.4
Weight density	γ_{γ}	1
Shear strength (other models)		1.25
Resistance (R)		
Earth resistance	γ_{Re}	1
Anchorage (R)		
Tensile and Plate strength	γ_a	1.1
Shear strength	γ_a	1.1
Compressive strength	γ_a	1.1
Bond strength	γ_a	1.1
Seismic		
Seismic Coefficient		1

OK Cancel

Click **OK** to close the Partial Factors dialog and then click **OK** to close the **Project Settings** dialog.

Select **Save** to save the new scenario

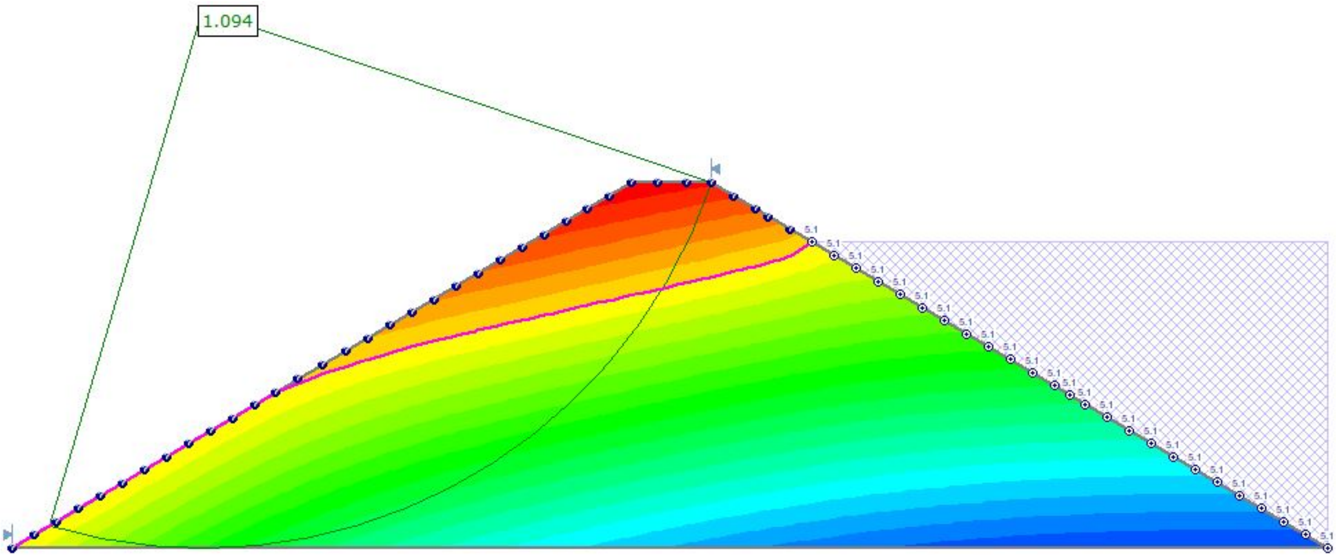
10. Compute

Choose **Compute** from the Analysis menu to perform the analysis. In the scenario Compute dialog, make sure the new scenario is selected for computing. Select **OK.**

Choose **Interpret** from the Analysis menu to view the results.

11. Interpret

As before, the Interpret program shows the results of the Bishop Simplified analysis. You can see that the over-design factor Γ is 1.094. This is still greater than 1, indicating that the slope is considered serviceable for this design approach. This also lies between the values of 1.07 and 1.14 obtained by Smith (2006).



Right-click on the failure surface and select **Show Values Along Surface → Base Cohesion**. You will see that all slices have a base cohesion of 9.6. This is 1.25 times less than the value of 12 kN/m2 entered for the material. This reflects the partial factor applied to the cohesion for Design Approach 1, Combination 2.

You can do the same thing to check the base friction angle. In this case, you will see a friction angle of 16.23°. With Design Approach 1, Combination 2, a partial factor of 1.25 is given for coefficient of shearing resistance. This is the tangent of the friction angle. So, we entered a friction angle of 20° for the material. The friction angle used in this analysis is, therefore:

$$\tan^{-1}\left(\frac{\tan 20°}{1.25}\right) = 16.23$$

12. References

Bond, A. J. and Harris, A. J. (2008). *Decoding Eurocode 7*, Taylor & Francis.

British Standards Institution. (2004). *Eurocode 7: Geotechnical design – Part 1: General rules*, BS EN 1997-1, London, UK.

Smith, I. A. (2006). *Smith's Elements of Soil Mechanics*, 8th Edition, Blackwell Publishing.