analysis & design software for engineers

Application Note - Slope Stability Analysis Worked Example

1   Introduction

This note describes the typical steps followed in setting up and analysing a slope stability problem with Limit-State:GEO. It also highlights some of the differences in approach to that adopted by the limit equilibrium method of slices.

All files used in this note are available in a zip file that can be downloaded from from http://www.limitstate.com/files/application-notes/LSGAN8/slope_stability_analysis.zip

Familiarity with the use of LimitState:GEO is assumed. The reader is referred to the user manual for further information on any features discussed in this note.

2   Problem definition

It is required to undertake a stability analysis of the 8m high drained slope shown in Figure 1.

In slope stability analysis, typically it is a factor of safety on soil strength that is required. (For a method of slices type approach a ratio of restoring forces/moments to disturbing forces/moments can generally also be interpreted as a factor on strength). LimitState:GEO is able to solve automatically for factor on soil strength to find the critical collapse mechanism without making the type of assumptions inherent in e.g. the method of slices.
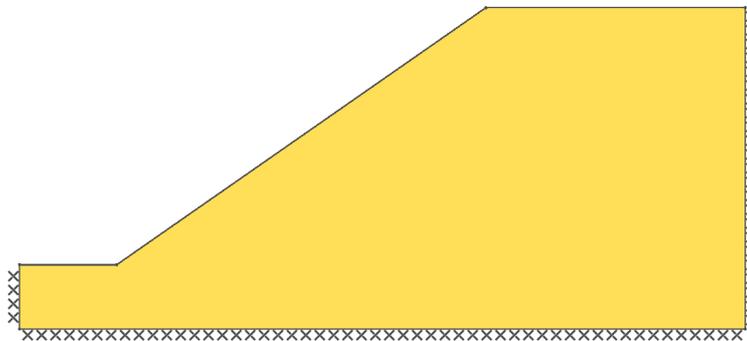

Figure 1: Slope stability problem geometry

3   Setting up the model

The LimitState:GEO model is created using the built in slope stability wizard:

1. Start the **New Project Wizard** using **File/New.../Slope Stability.** Problem parameters are entered in a sequence of tables. In the **Project** tab, enter any general information about the project. Then click **Next>**.
2. In the **Geometry** tab, set the problem geometry using the parameters shown in Figure 2. Click **Next>**.
3. In the **Water table** tab, leave the *Model water table* checkbox unticked for now. Click **Next>**.
4. In the **Materials** tab (Layer A), enter soil properties by using the **Create new material** option. Choose an appropriate colour for the soil and specify the soil properties using the values listed in Table 1. Click **Finish>**.
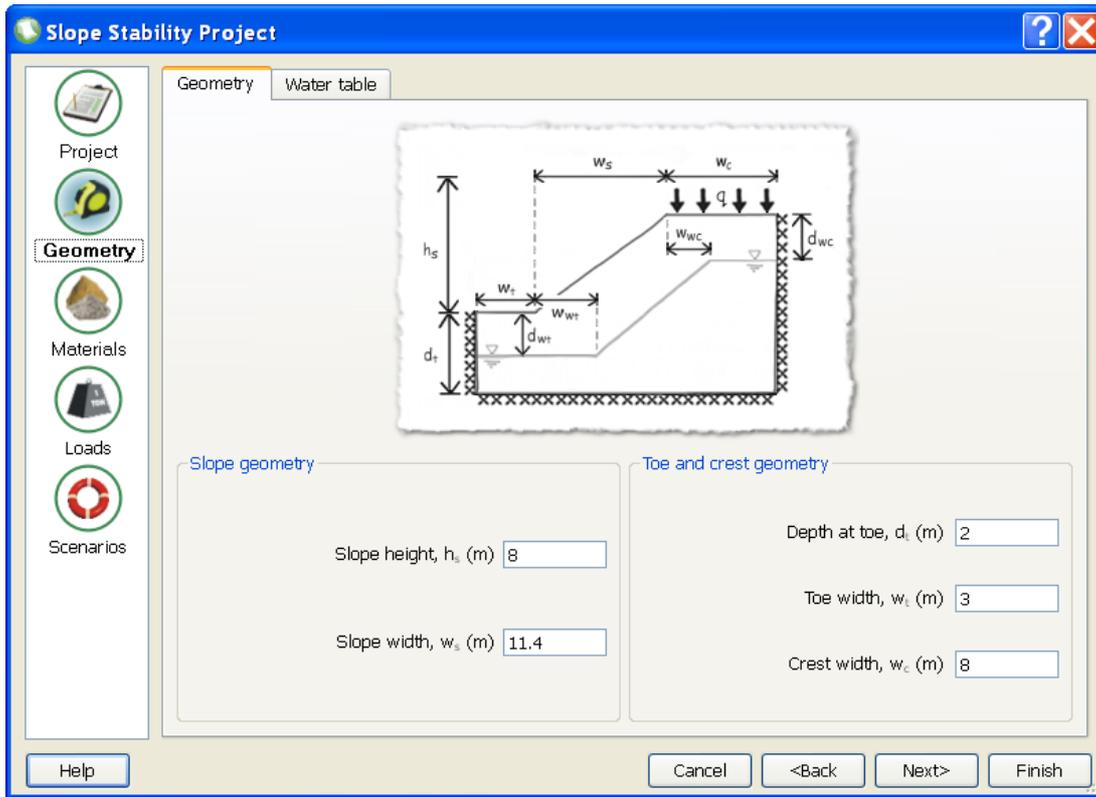
Figure 2: Slope stability wizard - geometry section

Soil name	Material drainage behaviour	c_u (kN/m^2)	c' (kN/m^2)	ϕ'	γ (kN/m^3)	γ_{sat} (kN/m^3)
Soil A	Always drained	-	7	25°	19.5	19.5

Table 1: Soil properties

5. The problem geometry now appears on the screen. Note that the boundary conditions on the base and sides are pre-set to **Fixed**.

6. Note that the Analysis Type (shown in the top toolbar) is set to *Factor Strength(s)*. In this mode the software will automatically find the factor on strength (applied to all Mohr-Coulomb materials in the problem) that leads to collapse. In this mode it is not necessary to set the **Adequacy factor** on any specific load or body force.

4 Running the analysis

LimitState:GEO searches all possible failure modes (restricted only by the density of nodes) and is therefore not restricted to a circular failure mode. There is no need to specify entry/exit points or search zones.

1. Using the default **Nodal Density** of *Medium* (available in the project level **Property Editor**) for initial checking runs, click **Solve** or ▶. This first solve returns an **Adequacy factor** of 1.271 together with the failure mode shown in Figure 3. This means that the soil strength (c' and $\tan\phi'$) must be reduced by a factor of 1.271 to cause failure, and thus the slope is safe against ULS. Click unlock 🔒.

2. Set the **Nodal Density** in the project level **Property Editor** to *Fine* to achieve a high level of solution

accuracy and **Solve** again. A slightly smaller value of **Adequacy factor** of 1.266 is returned.
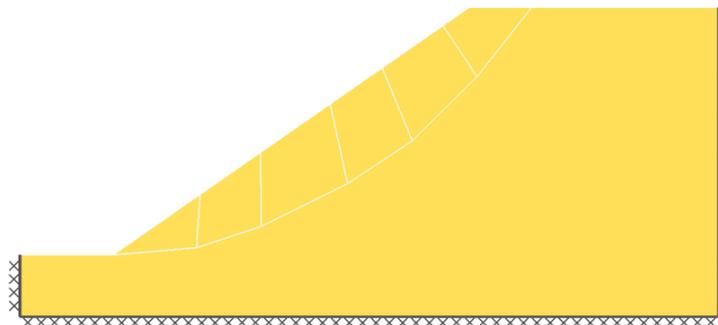

Figure 3: Main problem failure mode

5   Modelling Layered Soils

Often it is required to model several layers of soil in a problem. Layers may be built up individually or existing bodies of soil split into layers. In this case a two layer slope problem with layer interface 3m above the toe of the slope will be modelled. The factor of safety on strength will again be determined.

1. Unlock the project using 🔒. Revert to a *Medium* **Nodal Density** for initial checking runs.
2. Draw a horizonal line using **Draw/Line** or 🖊 at a position 3.0 m above the toe of the slope, linking the slope face with the far right hand vertical boundary. A new **Boundary** is added, splitting the existing **Solid** into two layers. (The x and y coordinate display at the right hand side of the **Status bar** at the bottom of the screen can be used to determine the height of the line which should be at $y = 5.0$m)
3. Create a new material for the upper layer using **Tools/Create New material** and use the properties listed in Table 2. Set the material of the upper layer to this new material by drag and drop and select **Replace** when prompted.

Type	Soil name	Material drainage behaviour	c_u (kN/m^2)	c' (kN/m^2)	ϕ'	γ (kN/m^3)	γ_{sat} (kN/m^3)
Mohr Coulomb	Soil B	Always drained	-	25	12°	18	18

Table 2: Soil properties

4. This solve now returns an **Adequacy factor** of 1.582. This means that the soil strength (c' and $\tan\phi'$) must be reduced by a factor of 1.582 to cause failure, and thus the slope is safe against ULS. Click unlock 🔒.

6   Inclusion of pore pressures

In LimitState:GEO a water table (inclined or horizontal) may be drawn in as appropriate or alternatively an r_u value may be used. In this example an r_u value of 0.3 will be investigated. (In LimitState:GEO the water table is used to define the boundary from which r_u is measured, typically coincident with the soil surface).

1. Using 🖊, draw a water table along the soil surface from left to right, linking the five surface **Vertices** of the slope (ensure the pointer 'snaps' to each of the vertices). To complete the water table click on a point to the right of the upper right hand **Vertex** in the problem and then right click and select *Finish*.

2. In the project level **Property Editor**, under **Water Table** set **Use** r_u **coefficient** to *True*, the **Av. Fill Unit Weight (kN/m^3)** to 18.75 and the r_u **Coefficient** to 0.3.

3. Click **Solve** or ▶ to analyse the problem. This solve now returns an **Adequacy factor** of 1.272 together with the failure mode shown in Figure 4). The factor of safety on strength is thus determined to be 1.272[1]

Further refinement of the analysis can be undertaken by increasing the nodal density (e.g. with a *Fine* **Nodal Density** a factor of safety on strength of 1.262 is obtained).
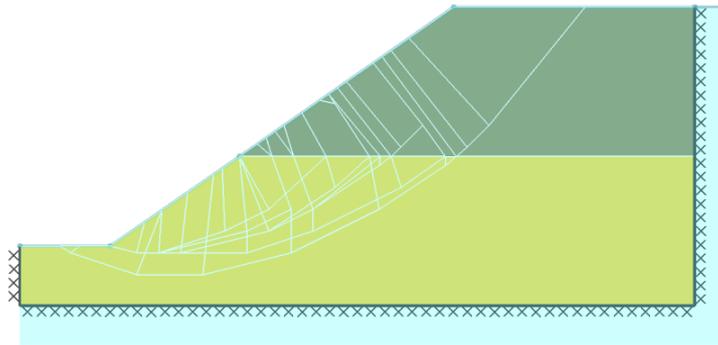

Figure 4: Failure Mechanism For Two Layer Slope Problem with $r_u = 0.3$.

For more information: www.limitstate.com/geo

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[1]This compares to a value of 1.25 provided by a Bishop Simplified method analysis, obtained by Whitlow for the identical problem based on a circular slip surface (Whitlow, 1990, Basic Soil Mechanics, Longman)