Slip on Weak Layer

1 Introduction

When a surficial soil overlies a considerably stronger material at depth, the potential exists for the surficial soil to slide along the contact between the two contrasting materials. The resulting slip surface is called a composite slip surface. In SLOPE/W you can analyze composite slip surfaces by forcing the slip surface to go below the interface of the two contrasting materials.

The purpose of this example is to show how to analyze a composite slip surface. Features of this simulation include:

- Analysis method: Morgenstern-Price (Constant function)
- Development of a composite slip surface
- Pore-water pressure condition modeled by a piezometric line
- Downstream water layer represented by a piezometric line only
- Presence of a dry tension crack
- Hand calculation of the some interslice forces on a single slice

2 Configuration and setup

With a composite slip surface, the slip surface enters the slope on the arc of a circle. When the slip surface intersects the interface between the weak layer and the bedrock, it follows the interface between the two materials until it intersects the circle once again, and then follows the arc of a circle up to the surface.

The grid and radius search option is used to develop a composite slip surface. The technique is to force the slip surface to go deep enough to hit the interface between the weak and strong materials, by placing the search radii below the weak layer, as shown in Figure 1. By placing the radii below the weak layer, the slip surface will hit the bottom of the profile and follow the bottom of the weak layer until it re-intersects the circular slip surface and exits the ground surface.

There are two different ways of handling the strong or impenetrable soil layer. It can be included in the analysis as a soil layer that has been assigned the bedrock (impenetrable) strength model. A second approach is to leave this soil layer completely out of the analysis. In SLOPE/W, the bottom boundary of the geometry is assumed to be a bedrock surface. In this example, however, a bedrock layer is included directly below the weak layer.

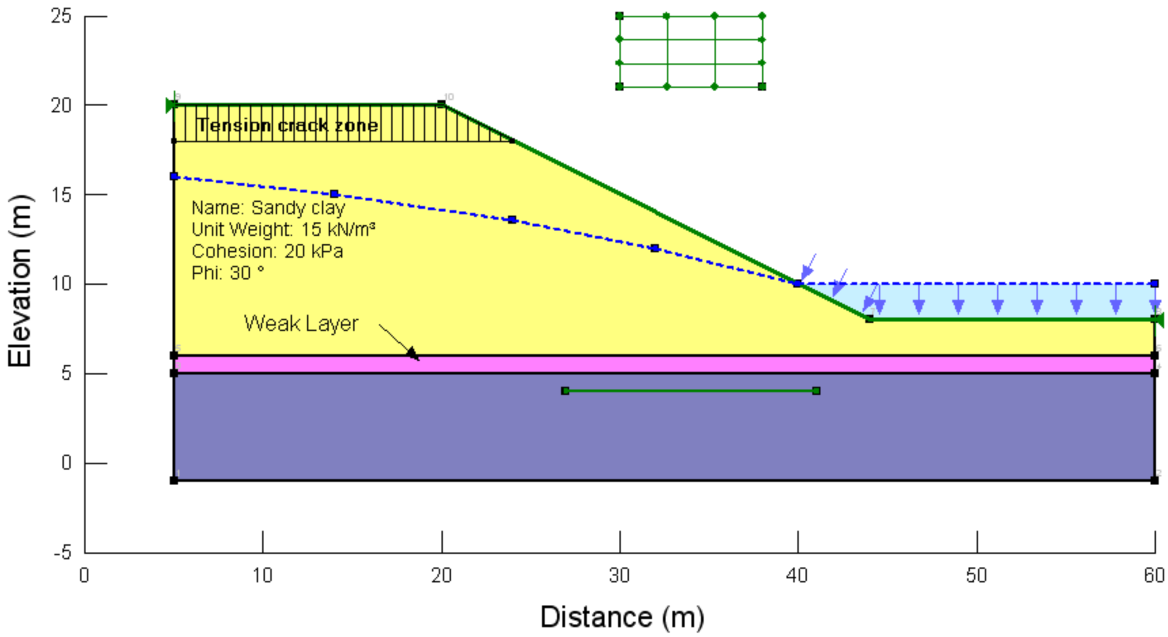

Figure 1 Geometry and grid and radius set up to model a composite slip surface

There are two hydraulic conditions that need to be included in the analysis. The first is the presence of a piezometric surface within the soil profile, and the second is a shallow pond that exists at the bottom of the embankment. When a piezometric line is defined, it is used by SLOPE/W to determine the pore-water pressures at the base of each slice. With the presence of the shallow pond water on the downstream slope, it is important to realize that the weight of the water layer is needed to compute the total weight of the slice and the piezometric line is needed to compute the pore-water pressure condition at the base of the slice.

In SLOPE/W, when the pore-water pressure of the ground surface material is under a positive water pressure, a water layer is assumed and the equivalent weight of water is automatically added to the weight of the slice. Note that in the previous version of SLOPE/W, you had to model the shallow pond water with a no strength water layer or a pressure boundary; this is no longer needed, as long as the pore-water pressure condition of the ground surface material is defined. A visual representation of the water weight and hydrostatic force is presented using a shaded area bounded by the ground surface line and the piezometric line and arrows indicating the direction of the force. Please refer to the "Slope with Ponded Water" example for further explanation of this feature.

Pore-water pressures at the base of each slice are determined by the relative position of the bottom of the slice to the piezometric line. Hydrostatic conditions are assumed to exist both above and below the piezometric line.

The last feature to be defined in this example is the presence of a tension crack zone. In this simulation, the tension crack is represented by a tension crack line placed at a depth of 2 m below the ground surface. The implication of this feature is that when the slip surface intersects the tension crack line, the slip surface does not continue along the arc of a circle, but is projected vertically upward to the ground surface. The location of the tension crack is indicated by the vertically hatched area at the top of the embankment, also shown in Figure 1.

3 SLOPE/W solution

The critical factor of safety for this example is 1.141 (Figure 2) and the optimized factor of safety is 1.054 (Figure 3). Note that the critical slip surface is generally circular in nature, as defined by the grid and radius procedure, except in the weak layer when the slip surface enters the bedrock layer and when the slip surface enters the tension crack zone. The optimized slip surface is not restricted to the circular shape, yet it is still controlled by the tension crack zone and the impenetrable bedrock layer.

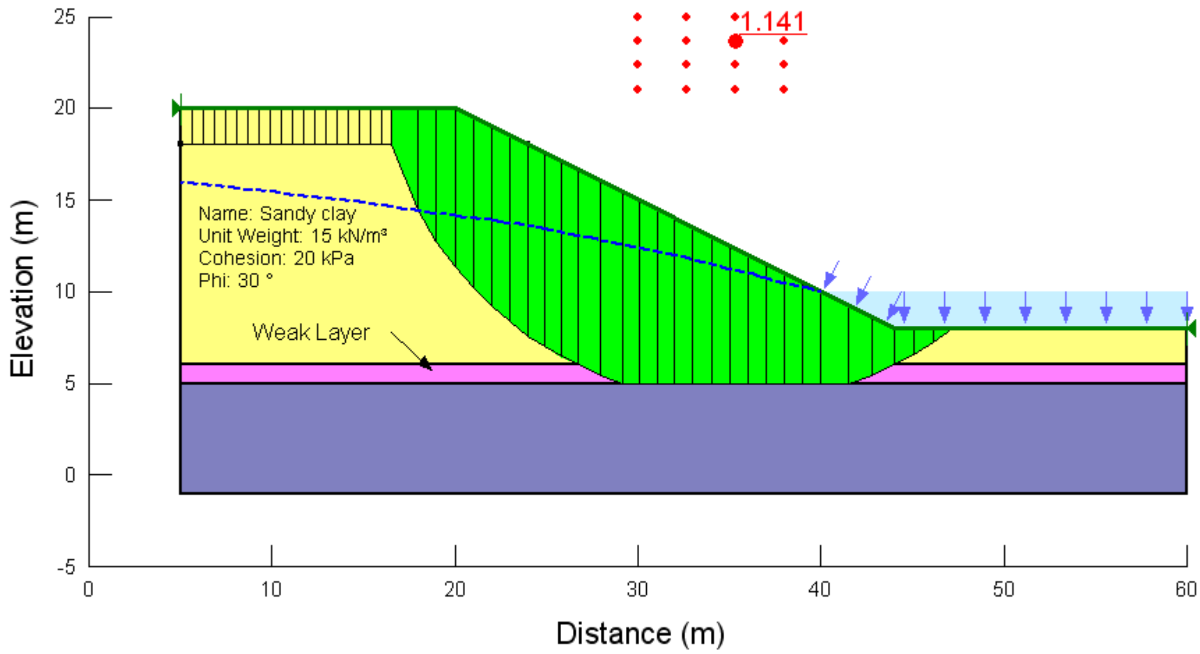

Figure 2 Critical slip surface and factor of safety

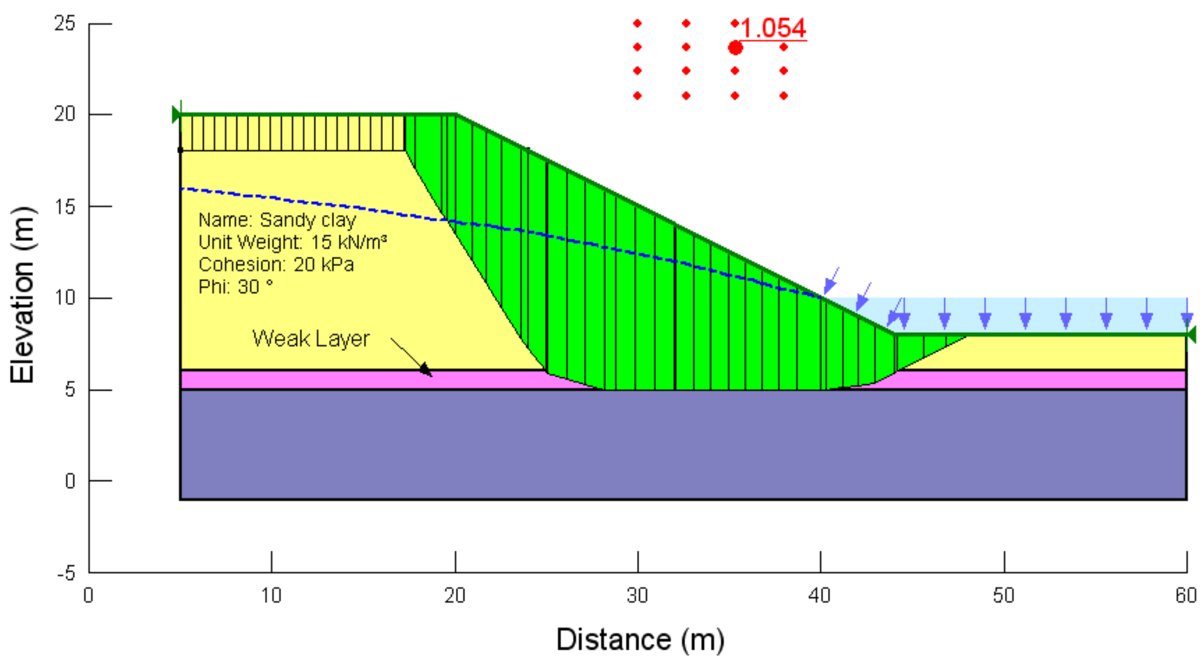

Figure 3 Optimized slip surface and factor of safety

4 Slice force verification

Viewing slice information is particularly useful for verifying that the presence of the ponded water has been appropriately modeled. Figure 4 shows the slice information for last slice under the pond water (number 36) of the optimized slip surface. The line load at the top of the slice is 24.243 kN per unit depth. This is the weight of the water layer automatically computed by SLOPE/W. By hand calculation, given a slice width of 1.236 m, the unit weight of 9.807 kN/m^2 and a water depth of 2 m, the water force should be 2 m x 9.807 kN/m^2 x 1.236 m = 24.243 kN per unit depth.

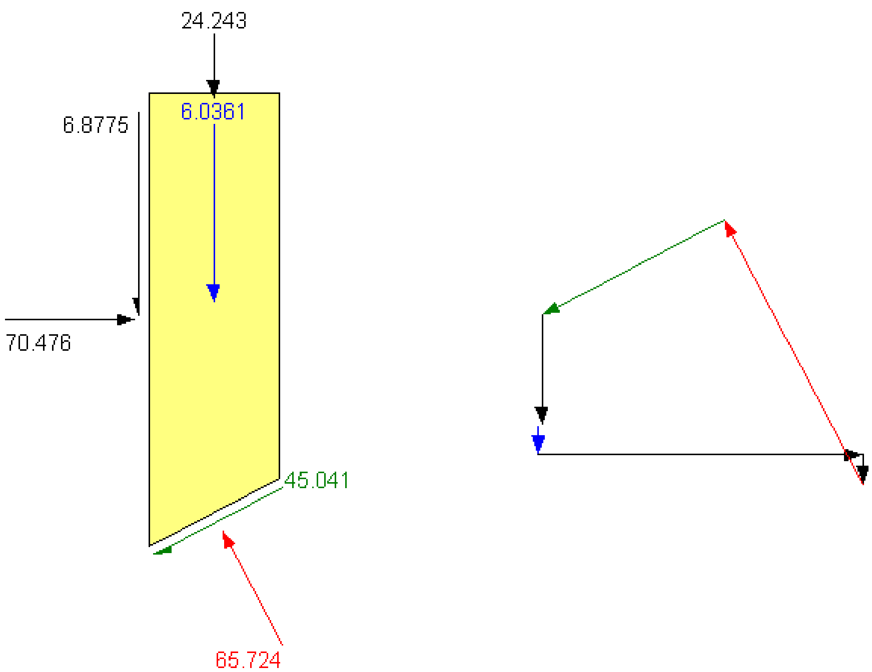

Figure 4 Slice forces and force polygon closure for Slice 35 of the optimized slip surface

The pore-water pressure at the base of the slice is provided for each slice in the slice information dialogue box. For slice 36, the pore-water pressure is 22.807 kPa, and the slice mid-height is 0.32557 m. Given a ponded depth of 2 m above the top of the slice, the pore-water pressure at the base of slice 35 should be (0.32557 m + 2 m) x 9.807 kN/m^3 = 22.807 kPa, which is exactly the pore-water pressure computed by SLOPE/W.

Also, from the slice information of slice 36, you can see that the base length is 1.397 m and the total normal stress is 47.046 kPa. With c' = 20, ϕ' = 30^o, and the factor of safety of 1.0544, the mobilized shear force can be calculated as:

$$\text{Mobilized shear force} = \frac{shear\ \ strength\ \ x\ \ base\ \ length}{FOS} = \frac{[c' + (\sigma' - u)\tan\phi']\ \ x\ \ L}{FOS}$$

$$\text{Mobilized shear force} = \frac{[20 + (47.046 - 22.807)\tan 30^o]\ \ x\ \ 1.397}{1.0544} = 45.040\ \ kN$$

The hand calculated mobilized shear force is 45.040 kN which is essentially the same as the shear force shown at the bottom of the slice presented in Figure 4.