Ru Bbar and Shansep Soil Strength

1 Introduction

The purpose of this example is to illustrate the use of Ru, Bbar, and piezometric line pore-water pressure options and their interactions to the total pore-water pressure along the slip surfaces. Furthermore, the S=fn(overburden) soil model also known as the Shansep soil model is used to illustrate the effect of pore-water pressure to the strength of the material. Special features of this example include:

- Use of a single circular slip surface
- Use of S=f(overburden) or the Shansep soil model
- Different combinations of Ru, Bbar and piezometric line
- Hand calculations of the generated pore-water pressure and the Shansep strength
- Multiple analyses

2 Configuration and setup

An embankment sitting on a foundation material is shown in Figure 1. The shear strength of the embankment is described by a Mohr-Coulomb model with the required input parameters, as shown in the figure.

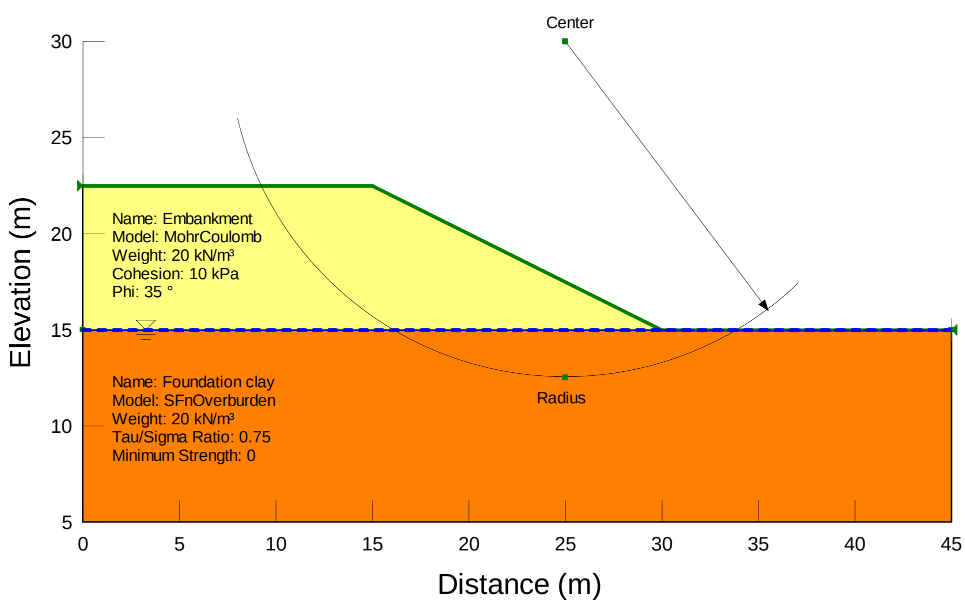

Figure 1 Profile for the example showing the soil layers, material properties and slip circle

The foundation clay uses a strength model that estimates the shear strength as a function of effective overburden at the base of a slice (i.e., Shansep soil strength). The effective overburden is computed from the weight of the slice and the pore-water pressure acting at the base of the slice. In this example, the Tau/Sigma ratio is assumed to be 0.75.

A single slip surface is analyzed by collapsing both the search grid and radius to single points. Also, a piezometric surface is defined along the surface of the foundation clay.

3 Case 1 – Ru Only

In this case, the pore-water pressure condition is assumed to be described with an Ru of 0.5 for both the embankment and foundation materials. The slip surface and the factor of safety of 1.301 are presented in Figure 2.

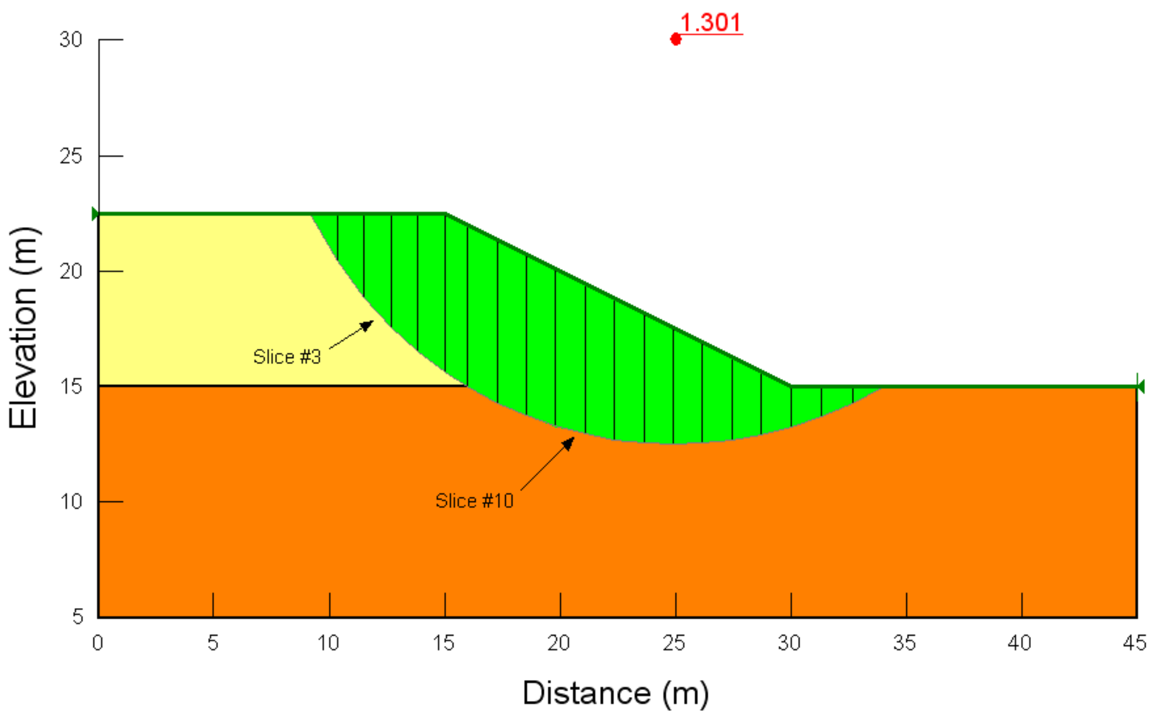

Figure 2 Factor of safety using Ru only

Using the View Slice Information feature in CONTOUR, you can examine the detail forces within a slice. For example, for Slice 3, the weight is 99.671 kN, and the width of the slice is 1.1623 m. The overburden stress is 99.671 kN / 1.1623 m = 85.753 kPa, therefore, the pore-water pressure based on an Ru of 0.5 will be 85.753 kPa x 0.5 = 42.877 kPa, as shown in the View Slice Information.

For Slice 10, the weight is 169.73 kN, and the width of the slice is 1.274 m. The overburden stress is 169.73 kN / 1.274 m = 133.226 kPa, therefore, the pore-water pressure based on an Ru of 0.5 will be 133.226 kPa x 0.5 = 66.613 kPa, as shown in the View Slice Information.

Slice 10 is in the embankment clay defined with the Shansep soil model. The effective overburden stress is 133.226 kPa – 66.613 kPa = 66.613 kPa. With a Tau/Sigma ratio of 0.75, the shear strength based on the Shansep model is 49.960 kPa. Since the base length is 1.3195 m and the final factor of safety is 1.3005, the mobilized shear force at the base of Slice 10 can be computed as (49.960 kPa x 1.3195 m) divided by 1.3005 = 50.689 kN. This mobilized shear force as shown in Figure 3 is 50.691; the small difference is due to numerical truncation.

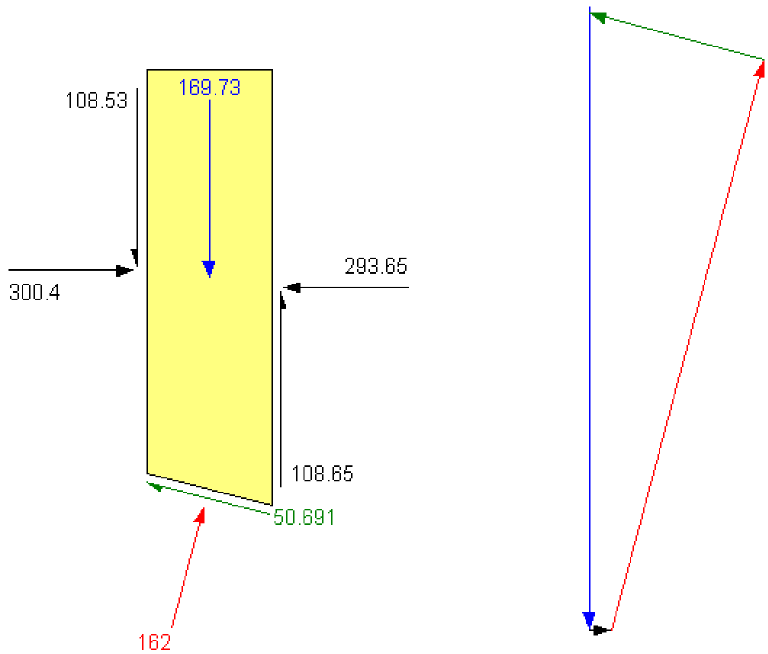

Figure 3 Free body diagram and force polygon of Slice 10

4 Case 2 – Bbar Only

In this case, the pore-water pressure condition is assumed to be described with a Bbar. Figure 4 shows the Bbar specification of the two soils. For foundation clay, Bbar is assumed to be 1.0, for the embankment, Bbar is zero, but the “Add Weight” option is specified as Yes. This signifies that the embankment is a newly constructed material, and the weight of the embankment will be contributed to the pore-water pressure calculation. The slip surface and the factor of safety of 1.443 are presented in Figure 5.

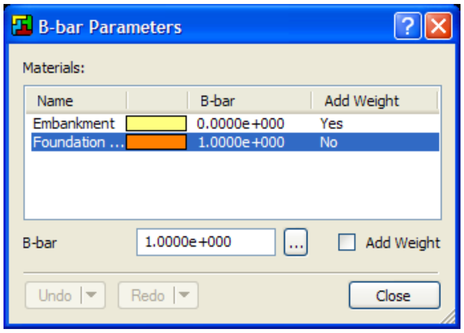

Figure 4 Defining the Bbar parameters for the two materials

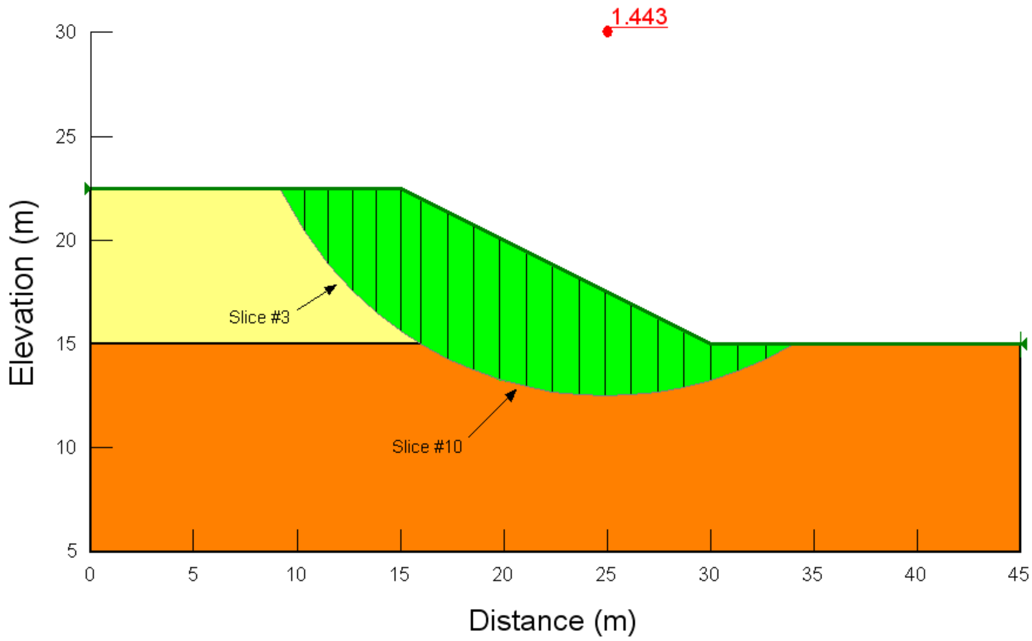

Figure 5 Factor of safety using Bbar only

Since the Bbar value for the embankment material is 0.0, the pore-water pressure for Slice 3 is zero, as indicated in the View Slice Information. For Slice 10, the height of the embankment soil sitting on the foundation is 4.78 m, and the overburden stress due to the embankment soil is 4.78 x 20 kPa = 95.6 kPa. The pore-water pressure when Bbar = 1.0 is equal to 95.6 kPa x 1.0 = 95.6 kPa. The weight is 169.73 kN, and the width of the slice is 1.274 m. The overburden stress is 169.73 kN / 1.274 m = 133.226 kPa. The effective overburden stress is 133.226 kPa – 95.6 kPa = 37.626 kPa. With a Tau/Sigma ratio of 0.75, the shear strength based on the Shansep model is 28.21 kPa. Since the base length is 1.3195 m and the final factor of safety is 1.4433, the mobilized shear force at the base of Slice 10 can be computed as (28.21 kPa x 1.3195 m) divided by 1.4433 = 25.80 kN. This mobilized shear force, as shown in Figure 6, is 25.80 kN; the small difference is due to numerical truncation.

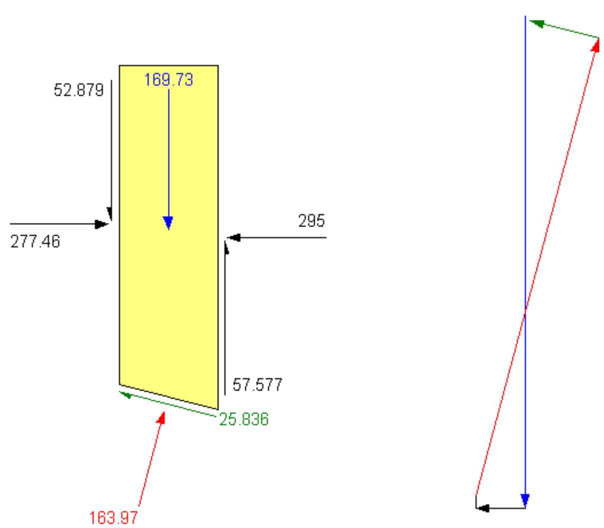

Figure 6 Free body diagram and force polygon of Slice 10

5 Case 3 – Piezometric line only

In this case, the pore-water pressure condition is assumed to be described by a piezometric line located on along the surface of the foundation clay. With this option, pore-water pressure is assumed to be hydrostatic, i.e, linearly distributed above and below the piezometric line. The slip surface and the factor of safety of 2.343 are presented in Figure 7.

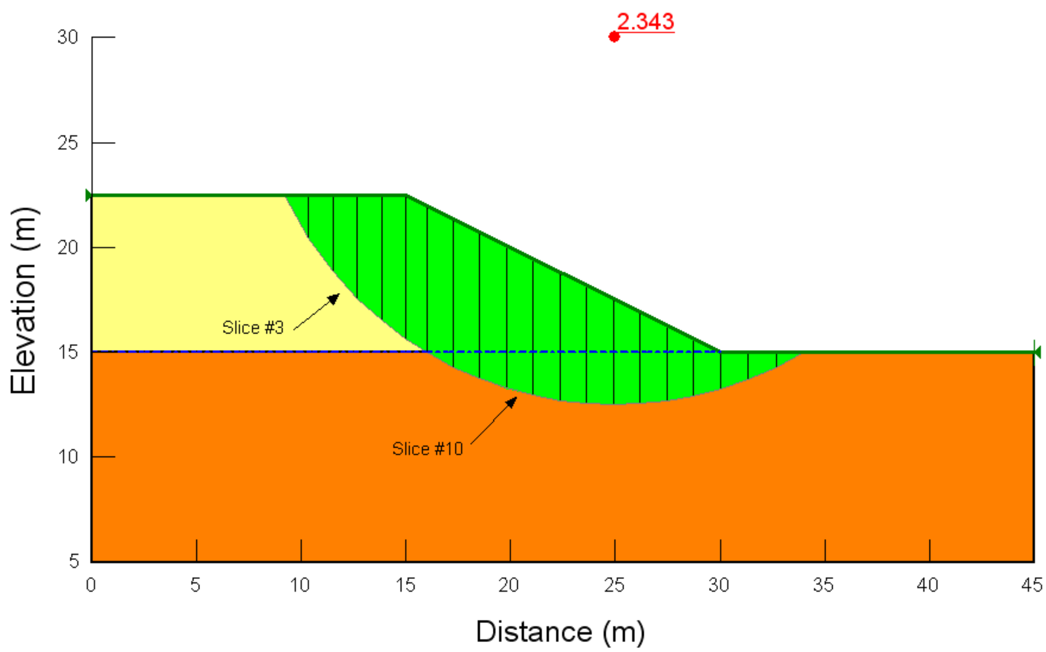

Figure 7 Factor of safety using piezometric line only

The vertical distance from the base center of Slice 3 to the piezometric line is 3.21 m above the piezometric line, therefore, the pore-water pressure is -3.21 m x 9.807 kPa = -31.50 kPa. For Slice 10, the vertical distance from the base center of Slice 3 to the piezometric line is 1.88 m below the piezometric line, therefore, the pore-water pressure is 1.88 m x 9.807 kPa = 18.475 kPa.

The effective overburden stress for Slice 10 is 133.226 kPa – 18.5 kPa = 114.726 kPa. With a Tau/Sigma ratio of 0.75, the shear strength based on the Shansep model is 86.045 kPa. Since the base length is 1.3195 m and the final factor of safety is 2.343, the mobilized shear force at the base of Slice 10 can be computed as (86.164 kPa x 1.3198 m) divided by 2.338 = 48.46 kN. This mobilized shear force, as shown in Figure 8, is 48.47 kN; the small difference is due to numerical truncation.

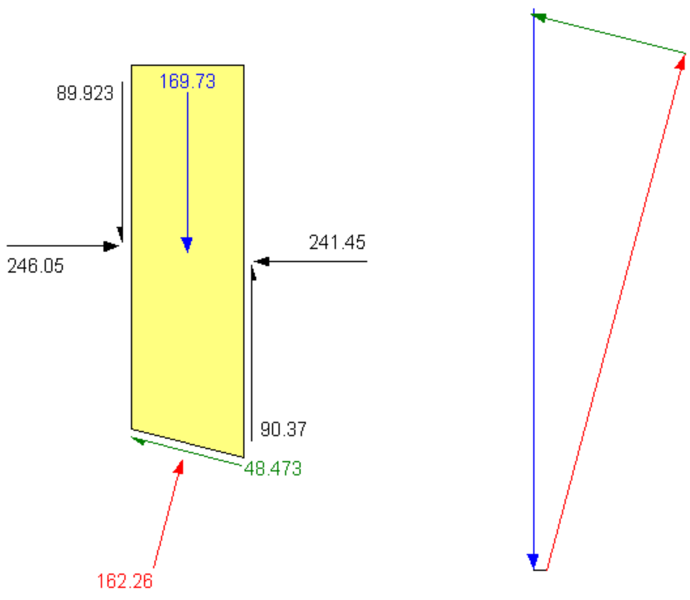

Figure 8 Free body diagram and force polygon of Slice 10

6 Case 4 – Piezometric line with Ru

In this case, the pore-water pressure condition is assumed to be described by a piezometric line with Ru. The pore-water pressure computed from Ru (Case 1) will be added together with the pore-water pressure computed with the piezometric line (Case 3). The slip surface and the factor of safety of 1.077 are presented in Figure 9. The factor of safety is decreased due to the increase in pore-water pressure.

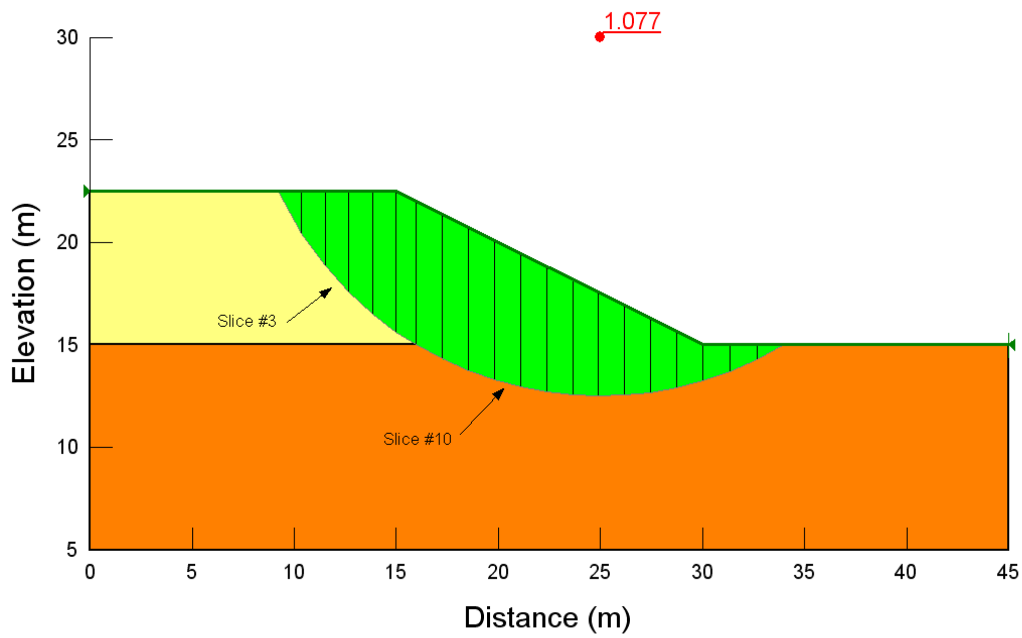

Figure 9 Factor of safety using Piezometric line with Ru

Using Slice 10 as an example, the total pore-water pressure will be 66.613 kPa + 18.48 kPa = 85.09 kPa, which is the same as shown in the View Slice Information.

The effective overburden stress for Slice 10 is 133.226 kPa – 85.09 kPa = 48.138 kPa. With a Tau/Sigma ratio of 0.75, the shear strength based on the Shansep model is 36.104 kPa. Since the base length is 1.3195 m and the final factor of safety is 1.0727, the mobilized shear force at the base of Slice 10 can be computed as (36.107 kPa x 1.3198 m) divided by 1.077 = 44.23 kN. This mobilized shear force as shown in Figure 10 is 44.22 kN, the small difference is due to numerical truncation.

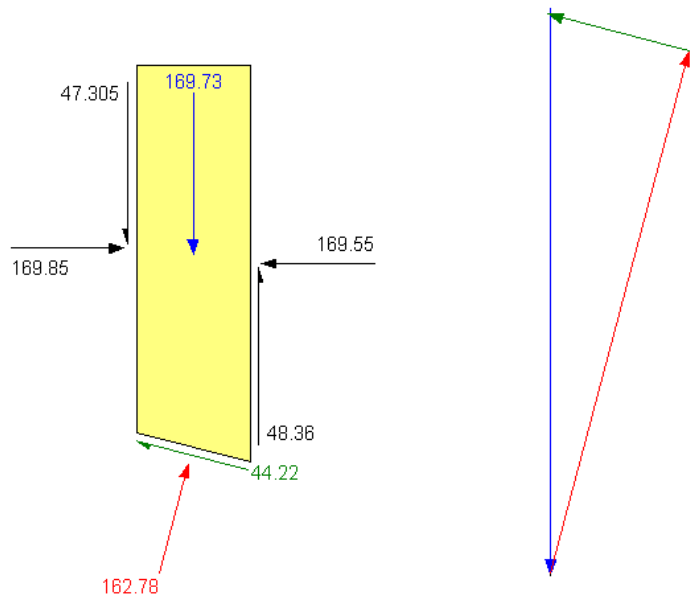

Figure 10 Free body diagram and force polygon of Slice 10

7 Case 5 – Piezometric line with Bbar

In this case, the pore-water pressure condition is assumed to be described by a piezometric line with Bbar. The pore-water pressure computed from Bbar (Case 2) will be added together with the pore-water pressure computed with the piezometric line (Case 3). The slip surface and the factor of safety of 1.016 are presented in Figure 11. As anticipated, the factor of safety is decreased due to the increase in pore-water pressure.

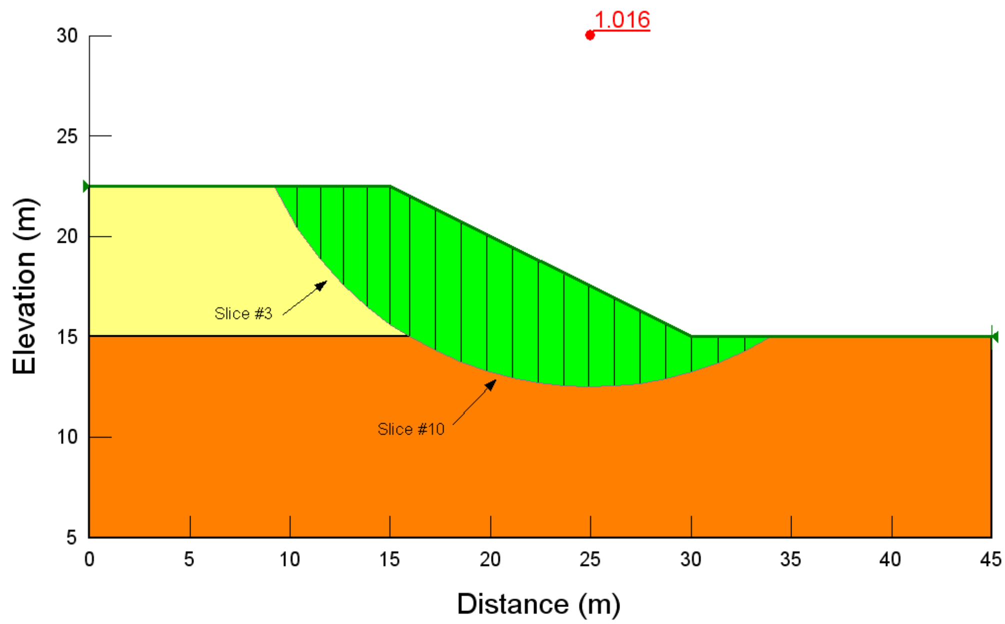

Figure 11 Factor of safety using Piezometric line with Bbar

Using Slice 10 as an example, the total pore-water pressure will be 95.6 kPa + 18.48 kPa = 114.08 kPa, which is the same as shown in the View Slice Information.

The effective overburden stress for Slice 10 is 133.2265 kPa – 114.08 kPa = 19.146 kPa. With a Tau/Sigma ratio of 0.75, the shear strength based on the Shansep model is 14.360 kPa. Since the base length is 1.3195 m and the final factor of safety is 1.016, the mobilized shear force at the base of Slice 10 can be computed as (14,464 kPa x 1.3195 m) divided by 1.016 = 18.65 kN. This mobilized shear force, as shown in Figure 12, is 18.70 kN; the small difference is due to numerical truncation.

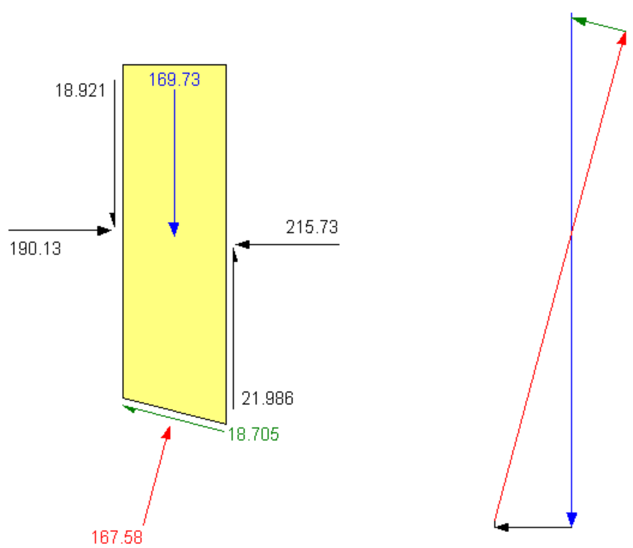

Figure 12 Free body diagram and force polygon of Slice 10